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EXPLORING MODERN SCIENCE

Alberta Edition

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Prairie Wings — *Richard E. Bishop*

Exploring MODERN SCIENCE

by

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EXPLORING MODERN SCIENCE is a completely re-set and re-illustrated text adapted from three of the authors' earlier works:

EXPLORING SCIENCE
ENJOYING SCIENCE
USING SCIENCE

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PREFACE

CONTENT: The content of this book is functional. It deals with the everyday surroundings of the child and with the grown-up world into which he will move. It covers most of the basic material in the grade seven unit studies of the Alberta Junior High School program. Teachers should bear in mind that the unit study method requires students to obtain information from several sources. For example, because of local interest, the teacher may want to supplement the material on "Animals" with additional data. Likewise, considerable extra source material is required in the study of a unit on "Magnets".

ORGANIZATION: This book serves as a basic source book to guide students in the unit studies in grade seven. Each unit can be related to the scope of the work dealt with in this grade. The review material at the end of each unit is designed to emphasize scientific thinking by giving the child practice in relating his knowledge to major principles.

ENRICHMENT UNIT: An additional unit has been added for enrichment purposes. Unit six is divided into two parts, AIR and WATER. It contains material for additional reading if desired. This content can be used as source material for parallel activities and also for silent reading exercises in science.

STUDY AIDS: Many study aids are included in this book. The daily test exercises at the ends of the problems and the review exercises at the ends of the units encourage mastery. Difficult words are defined and pronounced in the text where they occur. Questions and directions for observation assure attention to demonstrations. In the average classroom situation, no workbook will be needed.

DEMONSTRATIONS: Demonstrations are graded and practical. Every demonstration can be done either with standard laboratory equipment or with materials which can easily be obtained by the pupils. Elaborate setups are intentionally avoided.

ACTIVITIES: "Science activities for fun" constitute an important means of helping the child to participate in the learning experiences. These may be done either at school or at home and stimulate the child's interest in learning by doing.

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EXPLORING MODERN SCIENCE

Alberta Edition

Courtesy Steuben Glass, Inc.

INTRODUCTION

WHY IS THE STUDY OF SCIENCE NECESSARY?

OVER the radio came an amazing story of a man who dreamed in complete detail about the occurrence of a steamship accident. Then, having forgotten the incidents of his dream, he boarded a boat two weeks later, and the accident of his dream was repeated in reality before his eyes. Dates were given; names and addresses of the people involved were stated exactly. The dream was explained by the radio announcer as another marvelous display of the power of the supernatural.

You will encounter incidents similar to this throughout your life. You will often be asked to believe tall stories of unreasonable events, all of which are supported in full by details looked up after the story was started or invented by the mind of some imaginative person. If you are not careful you will find yourself impressed by the seemingly reasonable explanations until you believe what you know is not true. How can you protect yourself from the ignorance which you see around you?

The best remedy for ignorance and superstition is knowledge based upon correct methods of observation, measurement, and experimenting. You must learn to apply to your facts the processes of careful reasoning. The careful thinker withholds judgment until information is tested many times.

You will find as you study science that your ideas about many common beliefs are gradually changing. Some ideas you will test and discard; others you will be able to prove are sound. You may for a time lose confidence in knowledge, for you find that some things you once thought were true are really not based upon fact. But you should gain confidence in your ability to think as you go through these experiences.

Society is controlled by the majority of the people in any country. Unless you as a member of society are careful to apply to social problems the same calm judgment that you are asked to use in the science classroom, society will suffer. It is not enough to disbelieve foolish notions. You must learn to think through these foolish ideas and to expose their errors, not only to yourself but to others. You have a responsibility to yourself and to others to develop correct processes of thinking. The only kind of correct thinking is scientific thinking.

One rarely sees an image of the sun in eclipse upon the floor. These images were projected through tiny openings at the side of a Venetian blind. Knowledge of science enables one to understand his environment.

1. What is the method of scientific thinking?

If you were ready to learn to play tennis—batting the ball around the court, chasing it when you missed your shot, and generally doing a great deal of work with poor results—you would be greatly pleased if the world champion came along and showed you how to improve your game. Under his coaching you might develop into an excellent player. On a tennis court in a certain city playground an excellent coach trained two world champion tennis players, a boy and a girl. There are hundreds of better courts in Canada today, and there are perhaps many other boys and girls who have strength, speed, and courage to become champions; yet most players remain unskillful.

The difference between a champion and an ordinary player depends largely upon the methods each uses. If you start doing things wrong and practice wrong habits, you become worse instead of better, and soon are never able to learn to play correctly.

Can you learn to think? There are world champions in thinking, just as there are world champions in tennis. These expert thinkers make our important scientific discoveries. Champion thinkers do not get their names in the headlines often, yet they enjoy their skill more, and attain results more worth while, than do many famous athletes.

In science you are given the opportunity to be coached in the methods of thinking that have produced world champions! To benefit from coaching you must practice patiently, and

Courtesy Douglas Aircraft Co., Inc.

The presence of this crater in a fairly flat plateau raised a problem: "What caused it?" After careful observation, it was concluded that a meteor struck the earth and buried itself in this huge pit.

constantly try out against stronger competition. You will finally gain such skill that doing things right becomes a habit. An unskillful thinker can improve by using the right system.

Every game has its fundamentals. There are six steps in scientific thinking. These steps are finding a problem, gathering information to solve it, developing a hypothesis [hī·pŏth′ ė·sĭs], testing the hypothesis by experiment, drawing a conclusion, and testing the conclusion.

Just as a person cannot be anything but a loser in sports without skill in all the fundamentals, neither can he be anything but an unskillful thinker if he does not master these six steps.

What is a problem? A problem is a question which demands an answer. Mere idle curiosity about something is not a problem. The question must be one worthy of our time and effort. It may affect our immediate comfort, as when we try to decide whether to carry a raincoat or not. It may be a question of how to make friends. It may be some question that makes no immediate practical difference to us at all, as when we wonder how far it is to the edge of space.

In order to think clearly, make your problem exact by

stating it in words. You will then know what information you need.

How do we gather information? There are many ways of gathering information. If you wonder about carrying a raincoat, you may ask your mother if she thinks it will rain. Or you may go outside to look at the sky and get the feel of the air. Or you may call up the Weather Bureau or read the weather forecast in the daily paper. If you wish to get along better with people, you may watch others who have social skill, and see what they do that is better than the system you use. You may read the advice in the newspapers. You may ask your home-room adviser to suggest ways to improve your manners, appearance, or poise. If you wish to know about the size of space, you may go to the library and get books to read. You may talk over your ideas with your friends as you sit looking at the stars in the summer sky. You may even make a telescope if you are skillful and ambitious.

How do we form a hypothesis? A hypothesis is sometimes called a scientific guess. It is more than a guess, for guesses are usually formed as the result of a chance observation, and without a serious attempt to solve the problem. A hypothesis is a temporary conclusion—one that will be used or thrown aside, depending on whether it is useful or not.

If you decide to leave the raincoat at home, you have formed a hypothesis that it will not rain. You may decide that you can get along better with people if you smile more readily, try to talk about something in which they are interested, and learn some sport so you can meet more people. You may decide that the distance to the edge of space is equal to the distance light has gone in all the time since the sun started to shine, whenever that time was.

How do we test a hypothesis? Scientists test their hypotheses by setting up experiments in which they can make careful observations of what goes on when they make changes or measure objects or compare them with each other. You, too, must test your conclusions, whether you do it carefully or not.

If you left your raincoat at home and rain poured all day and you came home soaked, you have good evidence on which to form a conclusion. If you try out your new social skills

and find that you make several new friends, you have a way of testing your hypothesis as to why you had fewer friends than you wished to have. If you try to test your ideas about the size of space, you will probably find the problem too difficult to test. You will be stopped without any satisfactory thinking.

How do we form conclusions? Your conclusions result directly from your experiment. If you were soaked, you would readily draw a conclusion that your hypothesis relative to leaving the raincoat at home was wrong and should have been rejected. If you win friends, your conclusion is that smiling, being interested in people, and meeting them makes them interested in you.

Courtesy Bausch & Lomb Optical Co.

Experimentation is not new, for we see here a picture of the scientist Alhazen showing—almost a thousand years ago—that a stick thrust into water appears to be bent. The method of science, based upon understanding of all facts, however, is relatively new.

How do we test the conclusion? Many times a conclusion seems entirely sound and correct, but still is based upon an error. In the case of the rain, there is little doubt that you were wet. Reading about the amount of rainfall in the paper and comparing your experiences with those of your friends would verify your conclusions whether they needed verification or not. Your conclusions regarding making friends might be right; yet it is entirely possible that you made friends because you improved in ways you did not think about.

How do we solve a scientific problem? Scientific thinking is useful in everyday living. It saves much wasted effort and unhappiness resulting from errors. It makes us more open-minded and willing to gain information before we act.

Scientific thinking is not only useful but an absolute necessity in solving problems that require an exact answer. Let

us consider the problem, "How does the weight of oil compare with the weight of water?" Of course it is easy to say, "Oil is lighter."

But to gain evidence, observation is necessary. In lifting a can containing oil, it may seem lighter than a can of the same size containing water. It is also observed that oil floats on water.

To form a hypothesis, we decide that oil in general seems lighter than water. We select one kind of oil to test.

The experiment for determining the answer requires some apparatus. The bottle is weighed. Then it is filled with water. The bottle of water is weighed. The bottle is then emptied, dried, and filled with oil, and weighed. By subtracting the weight of the bottle in each case, you have the weight of the oil and the weight of the water. Here are two of the important factors in experimenting: measurement and comparison.

Forming a temporary conclusion is simple. An exact result is obtained by dividing the weight of the oil by the weight of the water. This number is called the specific gravity of the oil. A number is more exact in meaning than a word.

The conclusion that oil is lighter than water can be verified by repeating the experiment with many kinds of oils. It is always possible that you will find an oil heavier than water. Then your conclusion for each kind of oil would be limited to the kind of oil measured.

When you draw conclusions, be sure that you have the correct cause and effect related to each other. The cause must come first, and must always produce one, and only one, effect. Things that happen together may not even be related to each other. Verify every conclusion. Every cause and every effect must really exist!

Does thinking scientifically pay? Scientific thinking is worth while if you think that civilization, long life, comfort, freedom from disease, food, clothes, movies, the radio, newspapers, and almost every common thing you use are worth while to you. If you do not value these things, nothing can have much value. Scientific thinking has produced every completely correct bit of information you possess, and has made possible the producing of almost everything you own or use.

There is no correct kind of thinking other than scientific thinking. It is occasionally possible to get correct answers by chance. It is also possible to do many things so improbable that you cannot depend upon them. You might throw a baseball into a tomato can 100 feet away and have it stay there. But you do not believe it probable. Even when correct information is gained by chance, nobody knows if it is correct or not, or why it is correct.

If you do your scientific thinking as the result of knowing the rules and planning the steps, you will know when you know. When you do not know, you will know how much you do not know. You can plan with a feeling of confidence.

Exercise. *Complete the following sentences:* A —1— is a question that demands an answer. Before we experiment, we obtain all the —2— we can and form a —3— or working idea. An —4— involves weighing or measuring to obtain exact information. From our experiment we form a —5— which must be —6—. The only correct information we have is that obtained by use of the —7— method. The —8— must come before the —9— and must always produce the same —10—.

Science activity. Perform the experiment described in the problem. Make a balance that will actually weigh accurately. Make weights of small boxes or envelopes loaded with sand or shot. Compare them with the school weights.

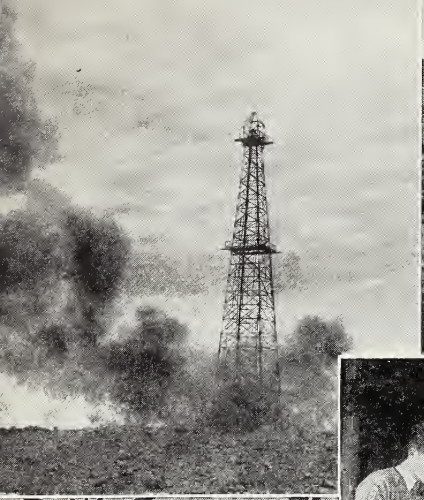
2. How does knowledge develop into science?

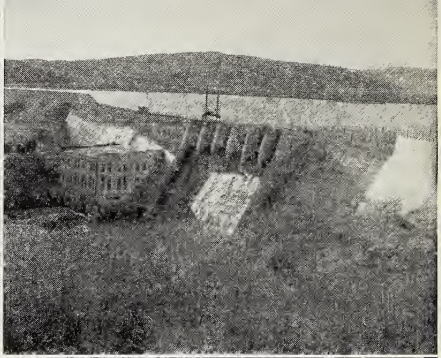
When the scientific method of thinking is successfully used in solving a problem, information is obtained. After sufficient testing, the information becomes an established fact — knowledge of which one is certain. When another related problem is solved, more knowledge is gained. As scientific experiments are carried on by many people and under different circumstances, many related facts are developed.

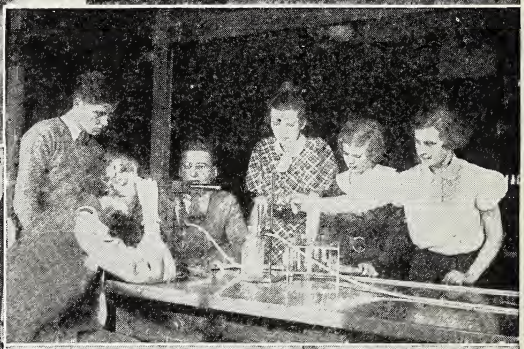
Finally so much information is developed that it begins to overlap, and it is apparent how the ideas are related.

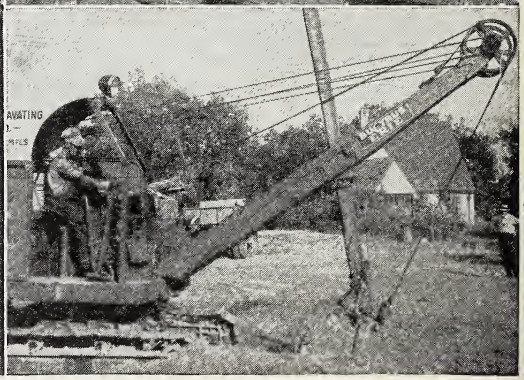
How is science organized knowledge? Until there is knowledge, it is impossible to organize it. But until knowledge is organized, it is not science. Science is the result of two processes: collection of facts and organization of the facts.

There are many ways of organizing knowledge. One branch









Top left and right, Alberta Government photos; centre, Bausch & Lomb Optical Co., bottom left, R.C.A. Mfg. Co. Inc., bottom right, Eugene Rosing photo.

Physics covers many subjects. The explosion at the top represents heat, and electricity is produced at the Calgary Power Plant, Ghost River. The radio antenna at the bottom is useful in producing sound. Light is represented by the students using the spectroscope to identify chemical elements. The steam shovel at the bottom represents machines.

of science is called physics—the study of physical changes of matter. Physics is a tremendous field of science—in fact all science is physics. Even life processes, the changes of growth and motion, are physical changes.

Because physics is so broad a science, it is further divided for convenience into studies of machines, heat, light, matter, sound, and electricity. In turn, each of these branches of physics is divided into smaller divisions for the convenience of those who wish to learn a great deal about some particular problem of heat, light, or any other branch of physics.

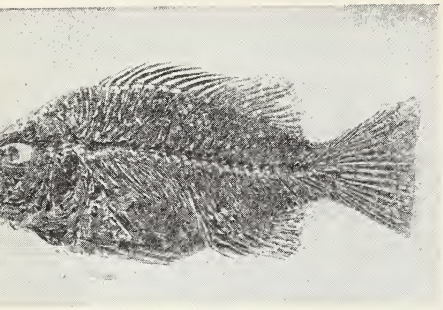
Another great field of science is chemistry. Chemistry is the study of the changes which take place in the make-up of matter. Chemistry is divided for convenience into two great fields: inorganic, which deals with those things not containing carbon, and organic, which is the study of carbon and the compounds of carbon. The word organic comes from the word organism, which refers to living things. It once was thought that the study of nonliving and living things was two separate branches of chemistry. It has since been learned that formation of organic compounds is similar to other chemical changes.

Chemistry overlaps physics, and one may study in universities the field of physical chemistry. In fact physics and chemistry are so often involved in the same changes at the same time that they are separated for study only for the sake of convenience.

A third great field of knowledge is biology. The prefix "bio" comes from the Greek word *bios,* meaning life. The two sciences related to biology are botany, the study of plants, and zoology, the study of animals. Each of these sciences is further divided into sciences of classifying living things, of studying their structure, of studying their habits, and many other fields of knowledge.

Biology overlaps chemistry and physics, for all life processes are chemical and physical changes. In advanced science one may study biochemistry, which is the chemistry of living things.

The science of the earth is called geology. Geology is chiefly a study of the crust of the earth and its history. To know the history of the earth, it is necessary to know biology, for



The bones of this fossil fish were found in a ball of dried clay. To understand how the fish was so well preserved and to know what kind of fish it was, requires an understanding of geology and biology.

the age of the rocks is determined in part by the types of fossil animals found in them. The age of rocks is also determined by study of the elements from which they are made, and particularly by study of radium and related chemicals. This study is both physics and chemistry. Study of the movement of the crust of the earth is both geology and physics.

Another great field of science and, in terms of its history, the oldest science is astronomy—the study of all the bodies in space. Astronomy is a branch of physics, for the stars are studied either by observing their motions or by studying their light, both of which are problems of physics.

All sciences finally depend upon mathematics for a means of expressing in an exact way what is learned by observation and experiment. Many of the divisions of science were set up before enough was known to realize how nearly all fields of science are really one field. The divisions of science are kept today because there is too much to study at one time, and because it is convenient to divide science into units small enough that they can be studied.

What is general science? When we study general science, we take whatever scientific knowledge we can find which helps us to explain our surroundings and which helps to solve our problems of daily living. We do not often think of the divisions of science, except as it is easier to get acquainted with part of our environment if we first find out the rules under which it operates. We would be confused if we tried to study living things and electric lights at the same time, although electric lights, properly used, make living things grow better. We study as much as we can understand, then try to relate one part of our environment to another.

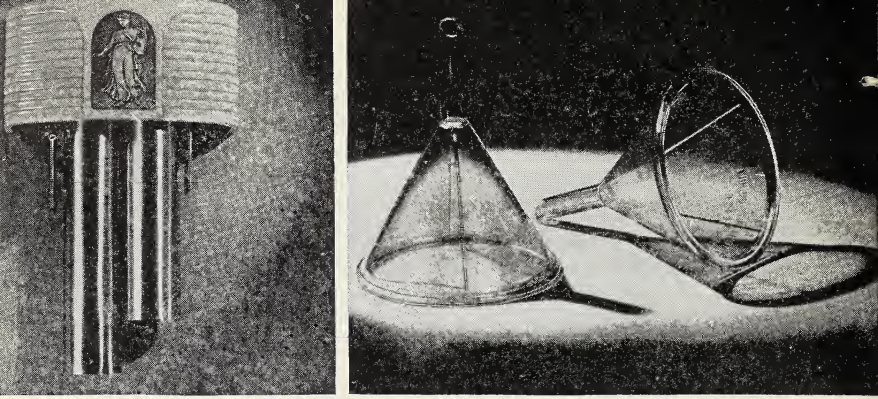
Is scientific knowledge still growing? At times we are inclined to think that there is nothing left in the world worth doing, for all the great discoveries seem to have been made. Such is not the case. The world is full of unsolved problems. Nobody really knows the difference between living and non-living things. Nobody knows just what matter or energy are. There are some diseases that nobody can cure. Nobody knows why we grow old. Nobody knows how the earth was formed. There are so many things to learn that only the shortness of our lives and the limits of our minds can keep us from learning some new thing as long as we wish to study.

Scientific knowledge grows through definite stages. As you studied the six steps in scientific learning, you learned that one of the steps was the formation of a hypothesis. The hypothesis is a working guess. Sometimes knowledge never gets beyond the hypothesis stage, because it is impossible to test it by an experiment. For example, the development of the earth is explained by a hypothesis, because it is impossible to perform an experiment to form an earth, just to see how it is done.

If a hypothesis is tested and a conclusion is formed, the resulting knowledge is called a theory. A theory is based on incompletely developed proof. We have many theories in science. The explanation of how life developed on the earth is a theory, for the origin of simple life has not been proved beyond a reasonable doubt. Yet the testing of the idea by digging for fossils, by study of living things, and by careful reasoning, indicates that our present knowledge is correct.

When a theory has been completely tested and verified by every possible method of which anyone can think, we have developed a law. A law is a statement of known facts. If it truly is a law, there is no doubt of its truth.

One of the most important things you must learn in order to be scientific in your thinking is to understand how completely a given idea is developed. If you state a theory as a law, and later somebody tests it further and finds it wrong, you have been guilty of careless thinking. Even great scientists have been, and probably again will be, mistaken in this way. At one time it was thought that the atom could not be broken up into smaller parts. Scientists were sure that this



Courtesy Monsanto Chemical Co. and Plaskon Co.

Scientific research has given us plastics which are used for such varied objects as doorchimes, funnels, portable greenhouses, and reading glasses. In each case the plastic has some marked advantage over glass.

knowledge was a law—that is, they believed that matter could not under any conditions be destroyed or changed to something else. Today we are much less sure of this idea. We are certain that matter can be changed to energy, and we do not know what becomes of energy under all conditions.

What is science? Science is a body of organized knowledge which has been developed by observation, experiment, and by use of the law of cause and effect in reasoning. Scientific

knowledge is the only accurate and correct knowledge which exists. The degree of correctness of all other knowledge depends upon how nearly scientific were the methods used in developing such knowledge.

Exercise. *Complete the following sentences:* Science is —1— knowledge which has been gained through use of —2—. Scientific thinking is the result of applying the law of —3— and —4—. A —5— is a general statement of known facts; a —6— is an idea or supposition supported by considerable evidence; and a —7— is a scientific guess or working idea. Study of the earth's crust is —8—. Study of living things is —9—. Study of the make-up of matter is —10—. The main divisions of physics deal with —11—, —12—, —13—, —14—, and —15—.

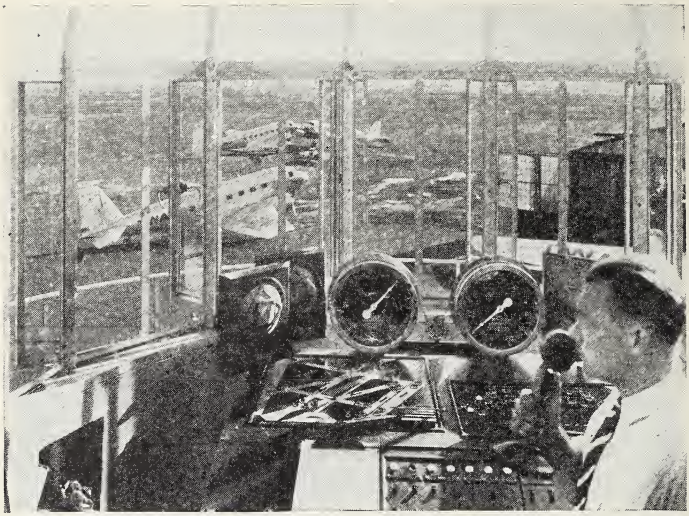
3. Can you profit from studying science?

Although you have studied science, you probably do not yet realize just what personal benefit you have received from your work. Some of these benefits should be immediately apparent to you. You know more about the world in which you live, and understand better the forces of nature to which you are subject. But science can help you with larger problems than this. Four of these are your problem of making a living, your place in the social community, your own personality, and your need to be an intelligent consumer.

Does science help in making a living? Many people depend upon science for their income. All doctors of medicine are scientists. So are some who fit eyeglasses. Dentists must study science four years before they study dentistry. Nurses must study the human body, chemistry, and foods, in addition to their special work in nursing.

Engineers are always trained in science. There are many kinds of engineers. Some draw plans for roads, some direct operations of chemical plants, some operate radio stations, some operate manufacturing plants. Airplanes are designed by engineers.

Industry employs hundreds of scientific specialists for research in producing new goods, and in producing standard goods more economically or efficiently. Many scientists are employed in Canada's Forest Service in the dominion and provincial agriculture departments; and in the Weather



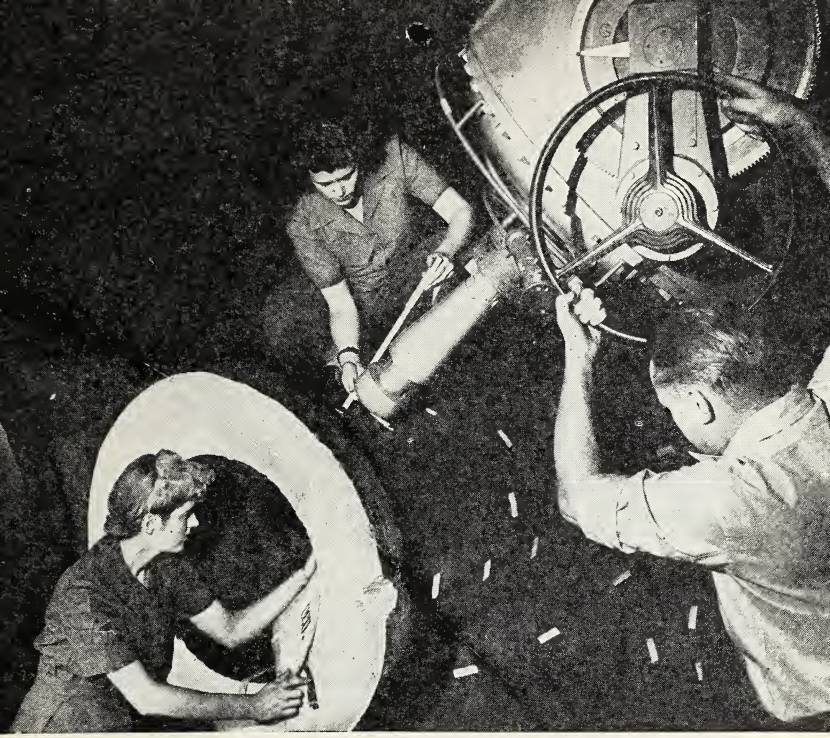
Courtesy Western Electric Company

On the desk of the control tower of the airport are controls for lighting the field, two wind indicators, and three loud-speakers, used to carry on conversations with pilots of the approaching planes.

Bureau. Radio, telephone, and telegraph systems employ a number of scientifically trained men.

In occupations related to scientific work, but not truly scientific in their nature, are actually hundreds of kinds of work. Agriculture, homemaking, cooking, clothing trades, barbering and beauty-parlor work, lumbering and manufacturing offer many kinds of work which are based to some extent upon scientific training. Men who install refrigerators, plumbing, and gas appliances are using science in their work. You can understand better the job for which you are training yourself if you have a good understanding of science.

Does science help improve society? Today there is great need for careful thought and restrained action in the world. Science teaches you to think before you act, whereas many forces are trying to lead you to act without thinking. We are addressed over the radio by men whose only aim is to get us sufficiently excited to do what they want us to do, whether



Courtesy General Electric X-ray Corporation

These people are using a million-volt X-ray unit to find out if there are flaws inside the heavy piece of steel. X rays can pass through heavy metal and other objects through which we cannot see. Since we cannot see inside such materials directly, we must use other aids for observation.

it is to vote for a pension plan or to buy a new kind of shoe polish. Many of the forces which are directing our lives today are governed by ignorant people who do not understand the meaning of their own acts.

You must learn that a majority is always needed for the operation of a democratic form of government, but also that a majority can be wrong. When Galileo stated that the earth revolves about the sun, he was a minority of one. But he was right. At the beginning of any attempt to solve a new problem, the majority is always wrong, for the majority does not have information to use in thinking. We have seen many experiments performed in government in this and other coun-

tries, but they were not called experiments. These experiments were offered as final, perfect solutions for the problems of the moment. A little thinking on our parts may keep us from getting involved in a costly experiment in government which may not work out well. We must solve our problems with our minds and not with our emotions.

Until scientists can have freedom to work everywhere in the world to solve the problems of production, distribution, and use of goods, we will have poverty. Social problems are so complex that nobody has much knowledge for their solution today. It is a mark of a person untrained in science to demand a quick solution and immediate action in solving problems. Such quick solutions are almost always wrong, and such immediate actions ruin the chances of finding a better solution.

Science is useful only when people permit it to be used. If scientists are forced to continue to work only on simple problems like those of physics and chemistry, we cannot hope for much improvement of our social conditions. We must work for change constantly while never changing so fast but that we can go back to what we had in case we make mistakes.

Can science improve your personality? There are still many people in the world today who are superstitious, ignorant, and opposed to learning. You may become one of them unless you obtain a broad background of knowledge. There are people who wear charms and carry good-luck pieces. Some have peculiar beliefs about witches and the evil eye. It is still possible to buy "medicines" to make others like you. You must of course learn that you cannot get something you want by any kind of wishful thinking, either with charms or without them.

You should be able, because of your study of science, to get rid of many of the fears which keep people upset. You need not be afraid that the world is coming to an end when you know that so far it has survived for three billion years. You need not worry about luck, for you know that cause and effect do not leave any place for luck. You will, of course, understand that you may not know all the causes and effects, and that many are not under your control. Yet you know that getting a job or passing a test or scoring a basket in

basketball is not the result of luck. You will learn to take responsibility for your part of the causes which get the effects.

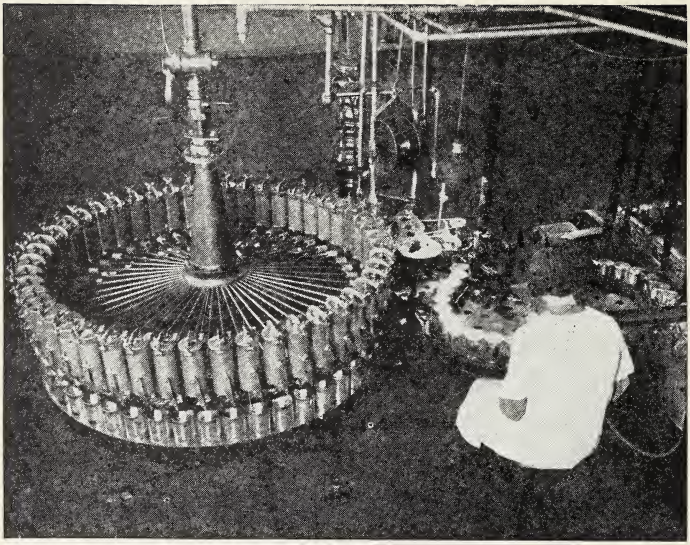
A scientist once said that there are two kinds of people in the world: the soft-minded and the hard-minded. The soft-minded solve their problems by running away from them, by denying that unpleasant things exist, and by trying to escape the consequences of their acts. The hard-minded look upon the world as it is, count carefully the probable causes and effects, face facts, and do not try to run away in daydreams or by blaming fate for their lives. Science should make you hard-minded. It is the healthier mental condition.

Courtesy American Red Cross

Are you reasonable and self-controlled in your behavior, or are you constantly in danger or difficulty because you do stupid things? Have you the show-off habit like this foolish boy?

Are you a wise consumer? Today it is almost as important to be a good consumer as it is to be a good producer. The world is offering such a variety of things to buy that we must obtain a sensible point of view toward wanting the fruits of scientific production. We probably do not spend more than half our money satisfying actual needs. The other half we spend on things that somehow seem desirable to us without their satisfying us at all. Many children chew gum because it satisfies temporarily a nervous need for moving the mouth, or because they have learned to like the flavor. Yet nobody needs gum. We frequently go to the movies when we may really need to play or to increase our circle of friends.

Many of the things which you will learn about in this book —the radio, new kinds of lamps, the automobile, vacuum cleaners, foods, and many others—may vary greatly in their value to you. If you consider your own needs instead of the appeals made by advertisers or the show your friends make of new equipment, you may spend your money more wisely than if you do not know the value of these devices.



Courtesy Irradiated Evaporated Milk Institute

In order to be an intelligent consumer, we should know how various products are made. Here cans are being filled with evaporated milk which has been radiated with ultraviolet rays. What does this mean?

You owe it to yourself to learn all you can in science about the operation, construction, and principles of the many devices which are available for your use. You should then decide which ones you want most. Nobody can afford them all, for even if he has the money to buy them, he still has not the time to use them.

Can science give a feeling of personal satisfaction? Related to the development of a stable personality is the need for a feeling of accomplishment. If you collect stamps or bake a cake or paint a fence, you have done something worth while. All these satisfactions are temporary, for their value soon is either lost or changed.

Many of the facts you learn in science, too, may change. But underneath the changing facts you have learned and will learn are certain principles. These never change. You have something worth while to which you can tie your personal experiences. Science gives you a feeling that you belong to

the world because you understand it. You can look into the sky and know what weather the clouds may bring. You can see in the stars the evidence of the vastness of space. You can look at a machine and know that man's skill brought it into existence. One of the best feelings in the world is the feeling that you are a part of your environment.

Exercise. *Make a table by ruling your paper into eight columns. Head the columns as follows:* HEAT, MACHINES, ELECTRICITY, PLANTS, ANIMALS, HUMAN BODY, FOODS, WEATHER. *In each column write the names of occupations in which the knowledge indicated in the headings is especially important. An occupation may be written into more than one column.*

4. Are you superstitious?

It is difficult for any of us to be certain that we are free from superstition. Many superstitions are so widely accepted that we do not even think of them as being anything but facts. Other superstitions are so appealing to us that we want to believe them even if we know that they are not true.

Are some superstitions based upon fears? People in general are afraid of those things they do not understand. The things that today are explained clearly and sensibly by scientific experiment were deep mysteries in ancient times. Many matters relating to changes in seasons, weather, sickness, death, and ordinary events seemed to primitive people to be controlled by some perverse fate. The custom grew of trying to bribe the fates or gods or devils, which were believed to be in charge of natural events, to be favorable. We still have a tendency to try to win good fortune by doing silly things which are in no way related to the cause of good fortune.

We cannot blame the ancient peoples too much for their fears. Before the invention of the microscope, bacteria were just as hard to imagine as were devils—both were invisible. The belief that evil spirits caused disease seemed reasonable. Until a definite cause-and-effect relation was proved to exist between bacteria and disease, there were no explanations much better than belief in evil spirits.

Do superstitions result from faulty observation? Many of our superstitions are based upon careless or inadequate

observation. The belief that the changing moon causes the weather to change is such a belief. There is also a tendency to draw evidence from too few cases. Thus if one sees a person who is pale, physically weak, and very bright, he concludes that these traits always go together. This is not the case, of course.

A type of faulty observation causes the naming of things that do not exist. There are many purely imaginary animals described in great detail—sea monsters, combination lions and eagles, and so forth—that never existed except in the mind of a careless or imaginative observer. Imaginary relationships are named just as are imaginary objects. Mind reading is believed to be such an imaginary relationship. For example, some women claim to have special intuition not possessed by men.

Do superstitions result from confusion of cause and effect? Many superstitions are directly the result of confusion of cause and effect. Two things that happen about the same time may be cause and effect, or both may be effects of the same cause, or they may be entirely unrelated.

Most of the superstitions about luck result from confusion of cause-and-effect relationships. If a baseball player wears a certain shirt when a hitting streak starts, it is not because of the shirt that the hitting continues. Yet many players will wear the same shirt until the hitting streak is broken. A rabbit's foot can't change your science test, but some pupil who takes the test in this problem will have a rabbit's foot in his pocket to bring him luck! In this test, such beliefs will bring failure.

How does superstition result from wishful thinking? Some people wish for a thing so much that they believe it to be true. Most people feel that there should be some way of making things even, so that a beautiful girl should be dumb, a slow worker exceptionally skillful, and a poor person unusually honest. Unfortunately such relationships are less likely to exist than are the opposites. Good things tend to go together.

Fortunetelling is dependent upon both a fear of the future and upon wishful thinking. When a person goes to a fortuneteller, it is to hear some news which he wishes to come true.

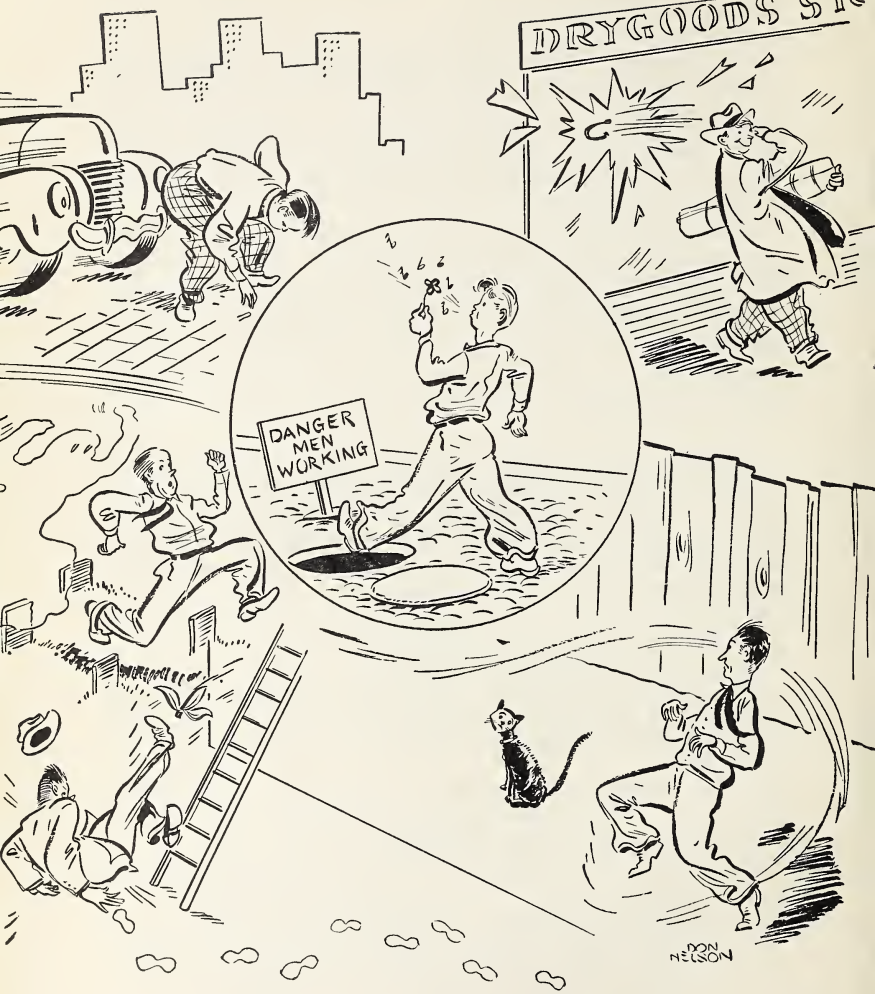
A skillful fortuneteller quickly learns what the person wants to hear, and tells it to him.

Most of our wishful thinking is designed to deceive ourselves, however. How many times have you imagined that some other person is deeply interested in you, only to find that such interest has existed only in your own imagination? How often have you decided that you were going to receive a certain gift, when in fact the gift you did receive was not at all what you expected?

Whenever many people do wishful thinking about common desires, a superstition is likely to develop. Such a saying as "It is an ill wind that blows no good" is an example. This sentence is really quite meaningless unless you consider it either as a plain statement of fact or as a wish. Most people use the saying to indicate the common hope for some good even in misfortune.

Exercise. *Make a table by ruling your paper into five columns. Head the columns as follows:* TRUE, FEARS, FAULTY OBSERVATION, CAUSE AND EFFECT CONFUSED, NONE OF THESE. *Classify the following statements by writing the numbers before the statement under the heading which best explains which are true, or why the false statements are superstitions.*

1. Soot on snow makes it melt faster.
2. In the spring toads seek water.
3. In planting vegetables it is important to plant them at the right time of the moon.
4. When salt is spilled at breakfast, plans for the day should be changed.
5. It is foolish to walk under a ladder, for one will have bad luck.
6. Frost forms on still, cold nights.
7. Rubbing warts with a potato will cure them, if the potato is thrown away.
8. Gypsies can tell fortunes better than other people.
9. Ghosts of those who have been murdered are more likely to return than are ghosts of those who die naturally.
10. Improper food will stunt the growth of children.
11. A winning athlete should use the same equipment to keep his luck.
12. Everyone needs a spring tonic to thin the blood.



Each picture illustrates a common superstition. Can you state what the superstition is, and why it is an unfounded belief?

13. You are more likely to get this wrong because of its number.

14. Winter weather can be forecast by the bark of trees and the fur of animals.

15. The ouija board often tells true events before they happen.

16. A willow stick, if properly held, tells where there is water underground.

17. People who rise early are more likely to become rich.

18. A birthmark is caused by the mother's receiving a shock before the child is born.

19. Vegetables are necessary for proper diet.

20. Finding a four-leaf clover or horseshoe will bring luck.

21. It is more serious to break a mirror than a valuable dish.

22. Lightning never strikes twice in the same place.

23. No one can escape the curse of a dying person.

24. Very young children who are very bright seldom amount to much.

25. People generally die at about the same age their parents die.

26. A slow worker almost always does things better than a fast worker.

27. Boils are a good sign because they purify the blood.

28. A person's character shows itself in his handwriting.

29. When the Big Dipper is right side up, the weather will be dry.

30. Dishonesty shows itself in a person's eyes.

31. Genius is a form of insanity.

32. Fat people usually eat too much.

33. It is proved that people can know by mental telepathy what is happening at a distance.

34. Almost all intelligent people are physically weaker than the average.

35. The arrangement of the stars and planets when one is born determines his fate.

A Review of the Introduction

The scientific method of thinking develops through six stages. A problem arises. A search for information follows. A temporary conclusion or hypothesis is formed. The hypothesis is tested by controlled observation, by experiment, and by measurement. A conclusion is formed. The conclusion is tested in as many ways as possible.

A conclusion is called a theory until it is definitely proved. Then a general statement of known facts is expressed as a law.

Science is defined as organized knowledge. The law of cause and effect is used in organizing knowledge.

An exercise in thinking

Write the numbers from 1 to 25 on a piece of paper or in your notebook. Each sentence in the first group below is a principle. Each sentence in the second group is an idea related in some way to one or more of the principles. Find the principle to which each sentence in the second list is related. Then after the number on your paper write the letter before the one related principle which best matches the related idea. You may turn back to the text for information if you wish.

List of principles

A. Everything that happens has some cause to produce each effect.

B. The best way to discover facts is by experiment.

C. A hypothesis is a scientific guess.

D. A theory is a supposition supported by considerable evidence.

E. A law is a general statement of known facts.

F. A superstition is a general belief which violates the law of cause and effect or is based upon fear or faulty observation.

G. Repeated testing of ideas is necessary to establish their truth.

H. A name does not necessarily stand for anything that really exists.

List of related ideas

1. The earth was probably formed from material from the sun.
2. A new boy in school made a good class president, so a new boy should always be class president.
3. In spite of the fact that she had not been exposed, Mary had measles.
4. Although a dairy claimed to sell extra-rich milk, its milk tested as average by the Babcock test.
5. Water underground can be located by use of a forked willow stick.
6. A lame man became well as the result of a miracle.
7. The children were excited while waiting for Santa Claus.
8. Every object in the universe is attracted by every other object.

9. What people mean when they say a star is in the heavens is really that it is in outer space.

10. All living things have a common ancestor.

11. The doctors did not find the mind when they operated.

12. Although the magic faucet on a glass plate has no pipes, water runs from it all the time.

13. Thieves are kind because a thief once gave his mother five dollars which he had stolen.

14. Those who say they can read character from handwriting cannot actually do so.

15. One man claims that his experiments show that people can transfer thought for a considerable distance.

16. Although patent medicines are worthless, people claim to be cured by them.

17. All matter is made up of small particles called atoms.

18. Boils are a good sign because they purify the blood.

19. A cup fell from a shelf and broke without any apparent cause.

Courtesy National Bureau of Standards

Observation is greatly aided by use of instruments. This microscope is used to study cloth fibers.

20. Nobody at a party could agree on what was meant by beauty.

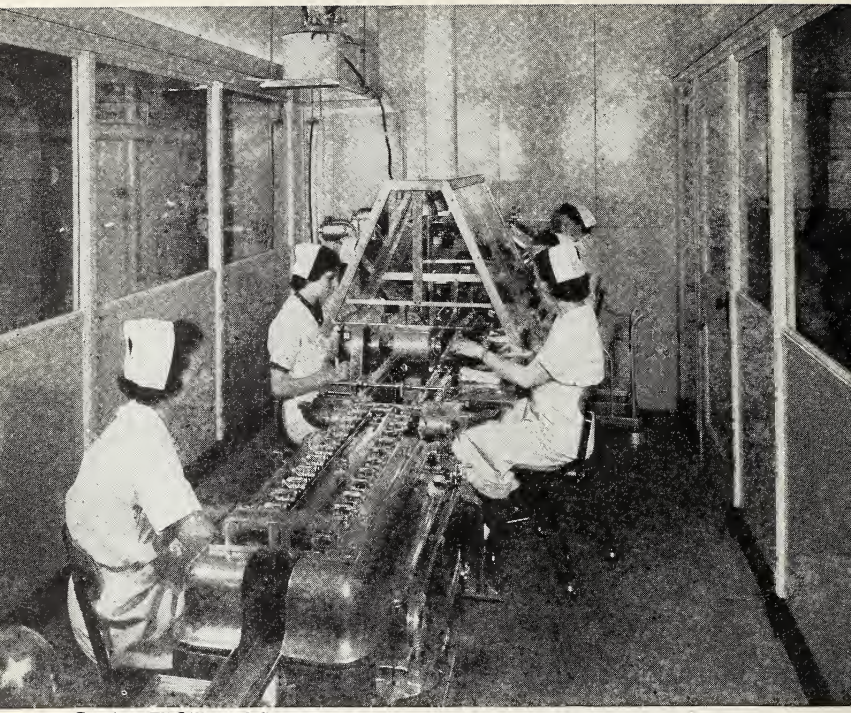
21. A four-leaf clover brings luck.

22. Edison made hundreds of tests to find a satisfactory lamp filament.

23. A birthmark is caused by the mother's receiving a shock before the child is born.

24. The total amount of matter does not change when a fire burns fuel.

25. The so-called "science" of reading character from the shape of the skull was worked out by measuring only a few people's skulls.

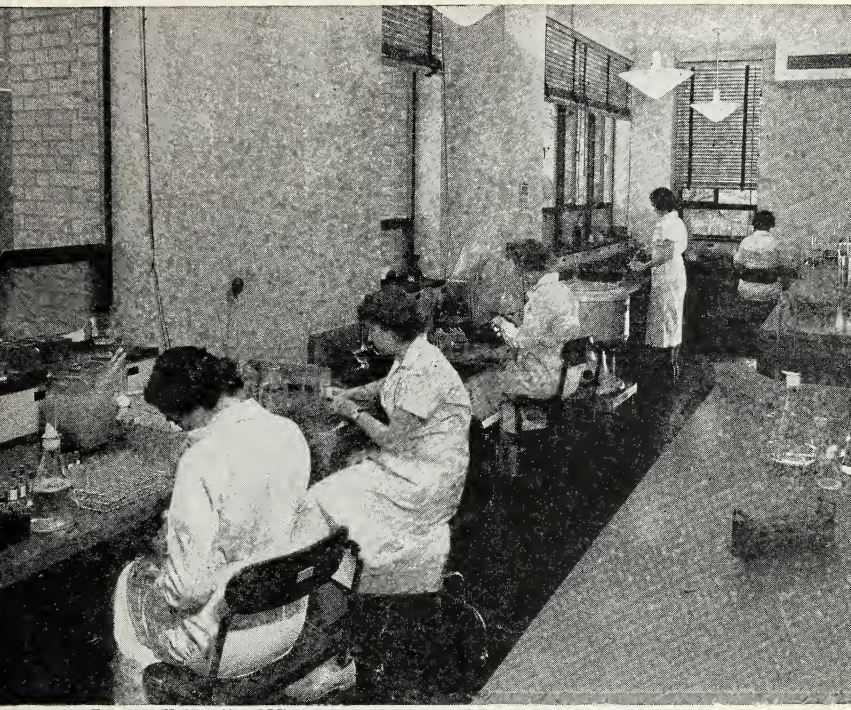


Courtesy Eli Lilly and Company

Most of the work of preparing medicines is performed by automatic machines. These women are operating machines which fill and seal small bottles called vials. Accurate measurement is very important in this work.

Some things to explain

1. Why are people afraid?
2. How has science helped to make you safer?
3. Why does science fail to develop among primitive peoples?
4. Why do scientists fail to receive as much publicity as criminals?
5. Why is it more important for the mother than for the father of children to be trained in science?
6. Why are girls in general less skillful in science than are boys? Do they need to be?



Courtesy University of Minnesota

These women are making blood examinations. Many diseases can be detected by study of blood. Many states maintain laboratories such as this to help diagnose disease. You can see how important the scientific method is in this necessary work.

Some good books to read

Carlisle, N. V. and Rice, C. C., *Your Career in Radio*

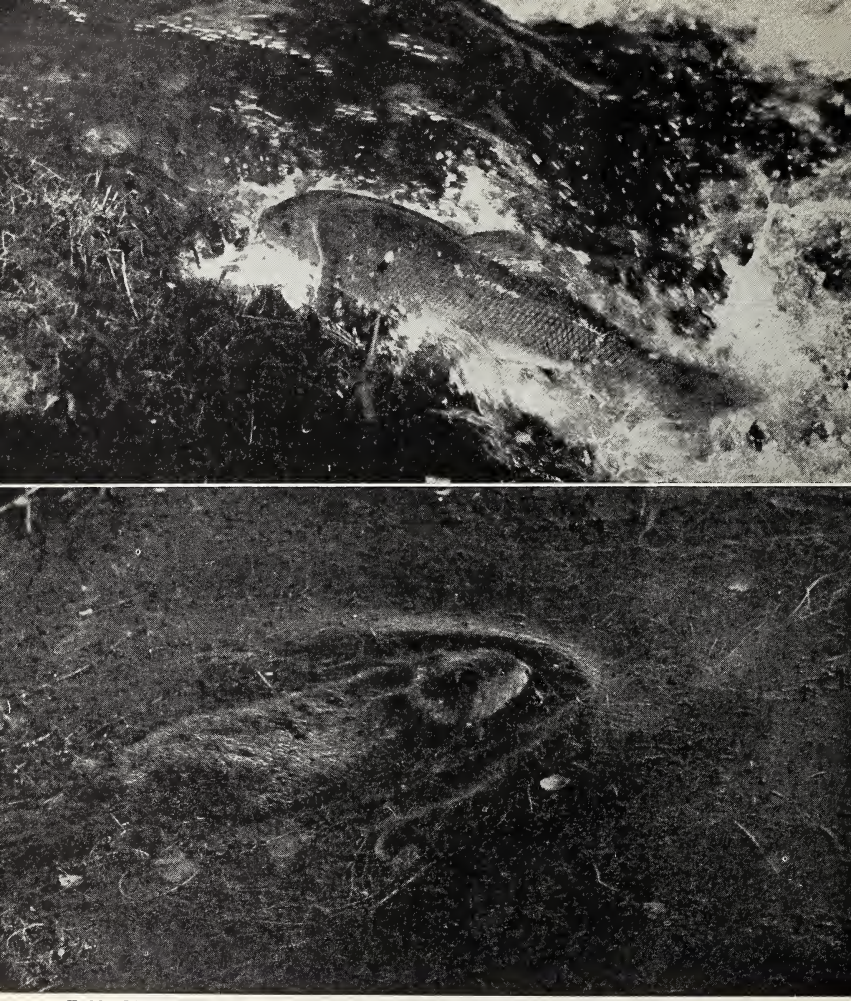
Curie, Eve, *Madame Curie*, A Biography

Frank, J. O. and Barlow, G. J., *Mystery Experiments for Science Classes and Science Clubs*

Gray, George W., *The Advancing Front of Science*

MacDougall, C. D., *Hoaxes*

Oliver, Jocelyn O., *Achievement: A Book of Modern Enterprise*



Tadda Photograph.

UNIT ONE

A BRIEF STUDY OF ANIMALS

Courtesy National Parks Service.

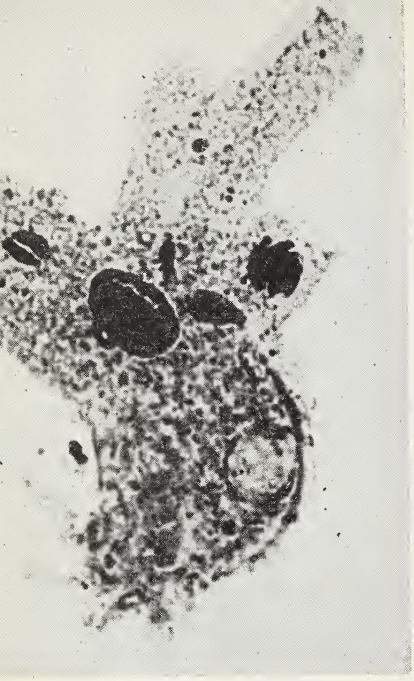
A calf elk (wapiti).

1. How are simple animals adapted to survive?

We generally know little about the simplest animals, because they are small and because they are not directly important to us. Yet there are at least 10 large groups, or phyla, of animals so simple that they have not developed an internal skeleton for support of their bodies. These animals range in size from one cell to several hundred pounds in weight, and vary just as much in structure as in size.

What animals are made up of one cell? We cannot hope to become familiar with all the 15,000 kinds of one-celled animals. These microscopic animals may live in the sea or in fresh water, in the bodies of other animals, or on moist soil. You can obtain specimens for study by putting a handful of hay in water or by putting water weeds in a battery jar. In the scum that forms on the surface of the water one-celled animals usually can be found.

A common animal grown in this way is the amoeba [ȧ·mē′bȧ]. It is about 1/100 of an inch long, and is a nearly colorless, jelly-like mass of irregular shape. The nucleus is visible under the microscope. The cell constantly changes



© General Biological Supply House

Although the amoeba is called the simplest animal, its one cell carries on many complex life functions. Can you see its nucleus?

shape as its protoplasm moves to form bulges on one side or the other. Motion by this means is slow. To obtain food, the ameoba wraps its body cell around material it comes in contact with, digests what it can by chemicals produced in the cell, and then moves away, leaving the undigested material behind.

Another animal found in the scum from the jar of water is the paramecium [păr′ȧ·mē′shĭŭm]. It is also a one-celled animal, but it has a definite shape—somewhat like a slipper with a pointed toe. Along one side is a groove which leads to a mouth. Inside the cell a tiny droplet forms in which wastes accumulate, and this drop is thrown off through the cell wall. The cell is covered with hairlike growths called cilia [sĭl′ĭ·ȧ], which are used to produce movement. The paramecium rotates as it moves either forward or backward, by whipping its cilia in the water.

Are sponges animals? Sponges always live in water, and usually in salt water. They lie anchored on the bottom of the sea or lake, and depend upon currents of water to bring them food. The cells grow in vase-shaped groups. Water is circulated into the open end by means of cilia, then into the central cavity, and out through the open end. The cells lining the pores digest food and pass the digested food along to other cells. These vase-shaped groups of cells may form huge clusters, or may be almost microscopic in size. The common bath sponge is made up of skeletons of many animals. The skeletons of sponges are not internal skeletons, but rather

are made up of horny fibers or glassy or limy materials.

What animals have hollow bodies? There are several groups of animals—the corals, the hydras, the sea anemones, and the jellyfishes—which have hollow bodies. All live in the water, and most of them live in salt water.

The hydra is found in fresh water, and is not more than a quarter of an inch long, and about as thick as a pin. It is made up of a hollow tube, and attaches one end to a stick or other support. The free end has a row of six or seven finger-like arms, arranged around an opening called the mouth. These arms are used in obtaining food. On these arms are many small stinging cells.

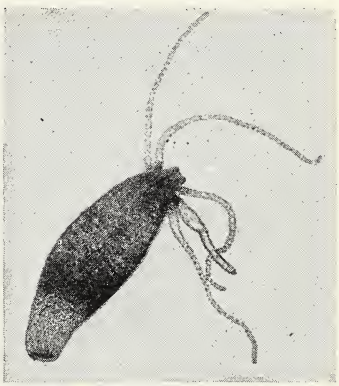
The hydra moves in various ways. It waves its arms and expands and contracts its body. It can also move along by sliding the lower end of its body along its support, or it can move like a measuring worm. It sometimes walks by using its arms as legs, or moves by turning slow somersaults.

The corals live in warm, shallow water in huge colonies. They build a kind of skeleton of lime. Each generation grows on top of the preceding generation, leaving behind materials which become part of the rock. The Great Barrier Reef of Australia, which was formed by corals, is more than a thousand miles long. Other types of corals form circular islands called atolls. Others grow near shore to form shore reefs. The corals are thus important rock-formers.

The sea anemone can commonly be found on rocks along the seashore at low tide. It looks as much like a flower as an animal.

Jellyfish usually are free-floating animals, and are about 97 per cent water.

How is the starfish adapted to live? There is an interest-



Hugh Spencer photo

The hydra is one of the small hollow-bodied animals. Note that one of its arms is contracted. Where is the hydra found?

L. W. Brownell photo

The sea anemone looks more like a flower than an animal. Its body is hollow, and it takes food into its central cavity.

ing group of animals with their parts arranged like the spokes of a wheel. This group includes the starfishes, the sea urchins, the sand dollars, sea lilies, and sea cucumbers. The most common of these is the starfish, which lies mouth down on the sand along the seacoast. The mouth is in the central part and is surrounded by five arms. The animals of this group have spiny skins, and generally are quite firm in structure.

How do the worms live? There are several groups of worms, each different from the others. The flat worms are simple in structure and are usually parasites in the bodies of other animals. Some live in snails, some in fish, some in higher animals. The tapeworm of man is such a worm, as is the liver fluke of sheep.

The roundworms are also often parasites, and are simple, tubelike animals. The hookworm and the trichina worm, which cause human illness, are members of this group.

The most complex worms are segmented, that is, their bodies are divided into ridges separated by grooves running around the body. The earthworm lives in moist soil through which it burrows to obtain food. In making a burrow, the soil passes into the worm's mouth, through the stomach and

intestine, and out of the body. The worm backs up to the surface to get rid of the soil, which is left at the opening of the burrow in little piles of dirt called castings. In this way the worm is able to burrow deep into the soil, usually to a depth of three or four feet. The earthworm comes to the surface at night to feed.

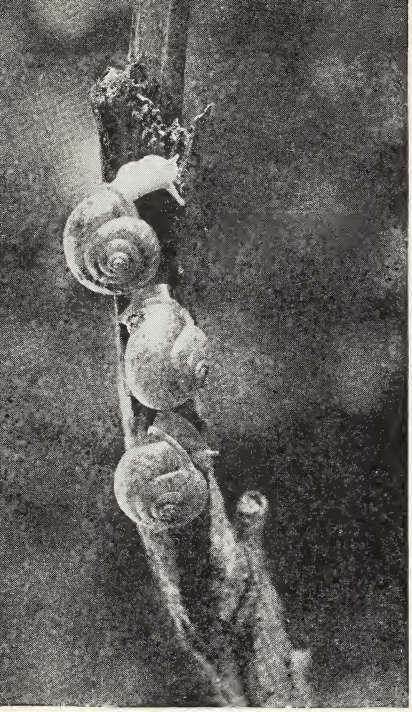
Because the worm breathes through its skin, it must be kept moist. This explains the fact that we see earthworms above ground only after rain.

Earthworms have simple nervous systems, quite complex digestive systems, special organs for getting rid of wastes, and means of circulating body fluids. They produce sperm and egg cells and reproduce by laying eggs.

What animals have soft bodies? There are more than 60,000 different kinds of mollusks, which are the soft-bodied animals. This group includes snails, clams, oysters, squids, scallops, and octopuses. Most members of this group have a shell which grows from a thin membrane, called the mantle, lining the shell. The shell is made of calcium carbonate, or "lime." Most members of this group have a muscular *foot* which contracts and expands to do the work of moving, digging, and holding to surfaces.

These long, or soft-shelled, clams belong to the group of mollusks which are the soft-bodied animals. Why does a soft-bodied animal need a shell?

L. W. Brownell photo



Hugh Spencer photo

These three garden snails live on land. They leave a trail of slime.

The snails have a single shell which is coiled spirally. Most snails live in water, but a few live on land. The common snail has a head, bearing a mouth and arms, and a foot used for crawling. The slugs are similar to snails, but have no shells and live on land.

The oysters, clams, and scallops have shells divided into two parts, called valves. These are hinged on one side so that they may open or close. Most of this group live in salt water, though some live in lakes and rivers. All have means of circulating water through their shells and bodies to provide a supply of food and air, and to remove wastes. If you have a clam in your aquarium you can see the current of water it sets up.

The shellfish are quite complex, for they have well-developed digestive and excretory (waste eliminating) systems. Their nervous systems are simple. They reproduce by means of eggs.

The large mollusks are the octopuses, the cuttlefish, and the squids. Some members of this class have no shell at all. The cuttlefish has an internal skeleton. Some members of this family can move in a peculiar way. They fill an opening called the mantle cavity with water, and suddenly force it through a small tube. They move rapidly through the water on the principle of a rocket.

The squid can protect itself by ejecting into the water an inky fluid which conceals it from its enemies. The octopus and squid have a row of arms adapted for seizing their prey. The mouth is in the central part of the body.

Slides (2x2 inch): Invertebrate animals—MK06. Chicago Apparatus Co.

Microscope slide: Amoeba, paramecium.

Exercise. *Make a table by ruling your paper into five columns. Head the columns as follows:* ONE-CELLED ANIMALS, HOLLOW-BODIED ANIMALS, SPINY-SKINNED ANIMALS, WORMS, MOLLUSKS. *Classify every animal mentioned in this problem in the correct column.*

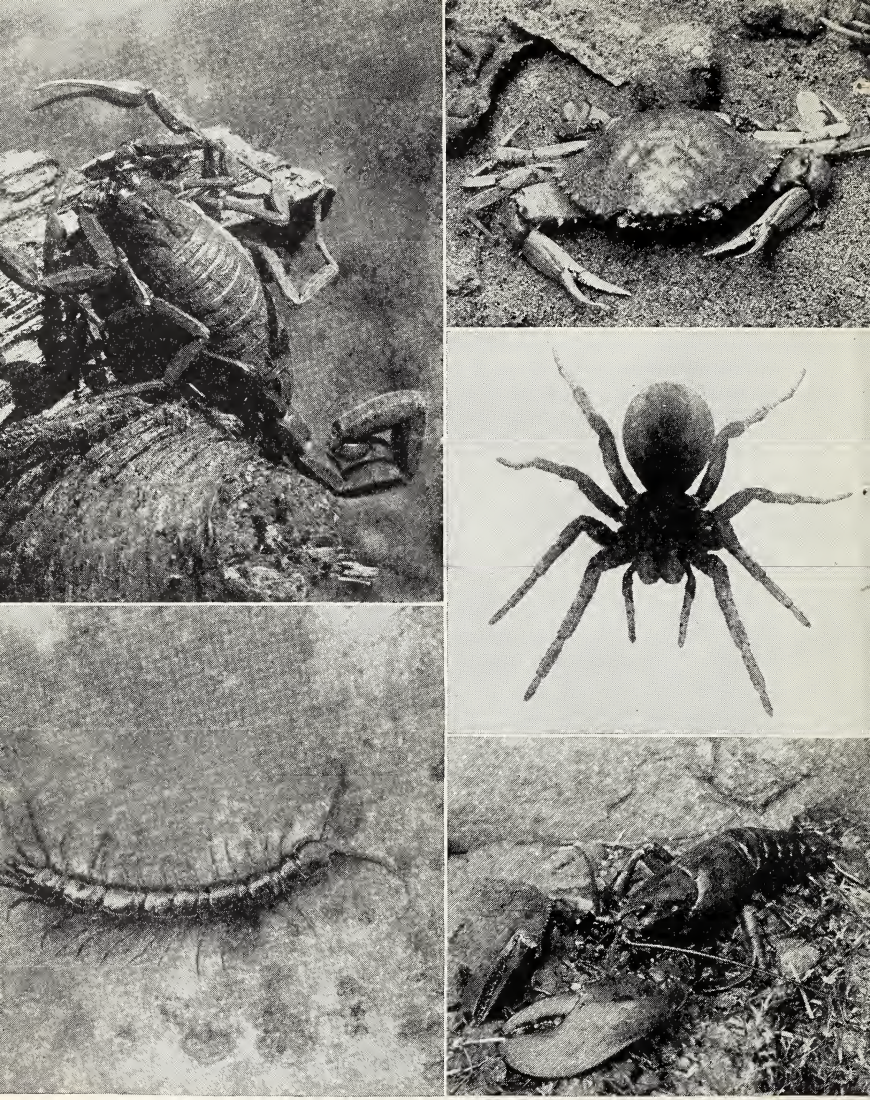
Science activity. Look up in a reference book one of the animals named in this problem, and report on it in class. Mention what it eats, where it lives, how it reproduces, and how it protects itself. If you can, make a large drawing to show the class.

2. How are animals with jointed feet adapted for survival?

As long as animals are limited in activities by simple structures, they do not adapt themselves well to complex environments. You probably have noted that most of the simple animals live in the sea or in some other place where the problems of getting food and surviving did not require any complex behavior. It was not until the development of a satisfactory skeleton and the resulting improvement in means of movement that any group of animals became outstandingly better adapted for survival than others.

Today the arthropods [är′thrŏ·pŏd, animals with jointed feet] greatly outnumber the other animals. There are more than three times as many kinds of arthropods as of all other kinds of animals combined.

The amazing success of the arthropods results from several features of their structure. They have skeletons made of a strong, light material called chitin [kī′tĭn]. The skeleton is located on the outside of the body in such a way that it serves to protect the complex inner structures of the animal. It also serves as a framework on which wings and legs are attached to act as levers. Muscles are attached to the skeleton. The arthropods can move more effectively than can any other group of animals.



Center right, © General Biological Supply House; all other photos by L. W. Brownell

These animals represent five groups of the arthropods. How do you recognize the centipede, the crab, the spider, the lobster, and the scorpion?

All arthropods have quite well-developed nervous systems to coordinate their complex organs. This nervous system operates by inherited patterns—that is, the behavior of arthropods is instinctive and complex.

The arthropods include several large groups of animals—insects, spiders, crayfish, crabs, lobsters, centipedes, shrimps, sow bugs, and barnacles. The three biggest groups of arthropods are the insects, the hard-shelled animals, or Crustacea, and the spiders.

What are the hard-shelled animals? The hard-shelled animals—the lobsters, crayfish, and crabs—generally live in water. They vary greatly in size, for the smallest are almost microscopic, while the largest lobsters may attain a weight of 14 pounds. They breathe by means of gills.

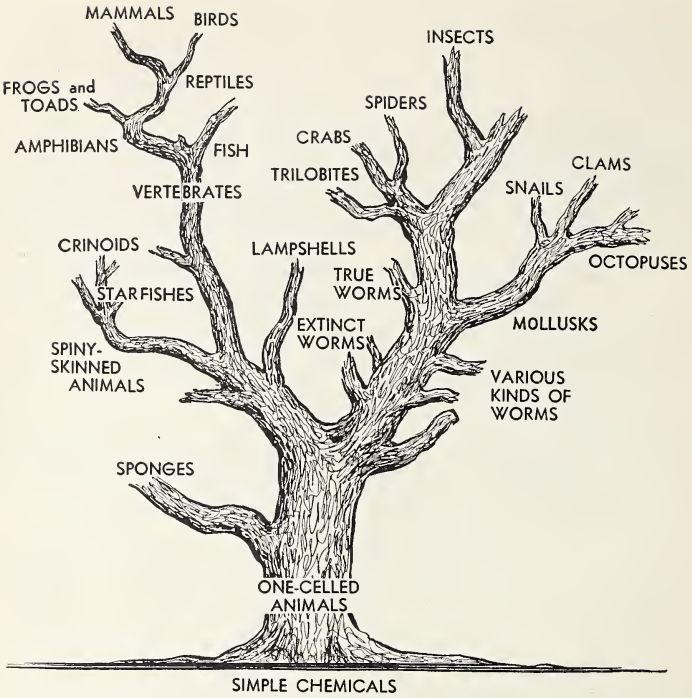
The crayfish is a typical crustacean [krŭs·tā′shăn]. It is found in rivers and lakes, where it hides under rocks and logs by day. From its hiding place it comes out at night to feed. It eats meat. Crayfish make interesting aquarium animals.

The crayfish grows inside its skeleton, but the skeleton does not increase in size. When the crayfish is too big for its skeleton, the old skeleton splits down the back, and the animal crawls out, leaving the old shell. It then grows a new skeleton. This process of shedding the shell is called molting.

There are many appendages upon the body of the crayfish. The large pincers serve for defense and attack. Some of the others serve as sense organs, some serve as means of securing and chewing food, and some of the smaller appendages on the thorax, or midsection, serve as legs. These appendages have the unusual power of growing if broken off. Growth starts at a certain joint and continues until the new appendage is as large as the old.

What are the spiders and their relatives? The spiders and their relatives are numerous. They live on land, and have either book lungs or breathing tubes, or trachea, or both. All members of this group have eight legs, and do not have antennae, or feelers. Some of them — the scorpions — have pincers. All of this group eat by sucking the juices from their prey.

Scorpions are noted for their poisonous sting, which is



This "tree" shows the relationship existing between different groups of animals. It is believed that the animals on the higher branches developed through stages similar to the simpler forms below them on the same branches.

located at the end of the jointed abdomen, or "tail." They live in the warmer sections of the United States. Their food consists of large spiders and insects, which they seize with their pincers and sting to death. Scorpions do their hunting at night.

The spiders are also eight-legged animals, but they have no pincers and no poison sting. The head and thorax are grown together, and the abdomen is not divided into segments or joints. Most spiders have four pairs of eyes.

The webs of spiders serve not only as traps to catch food, but as elevators and bridges. Many spiders travel by spin-

ning threads which are carried by air currents, taking the spider along. Some spiders spin bags in which they carry their eggs. Others spin bags, but after filling them with eggs leave them in a safe place for the young to hatch. Some spiders carry their young on their backs.

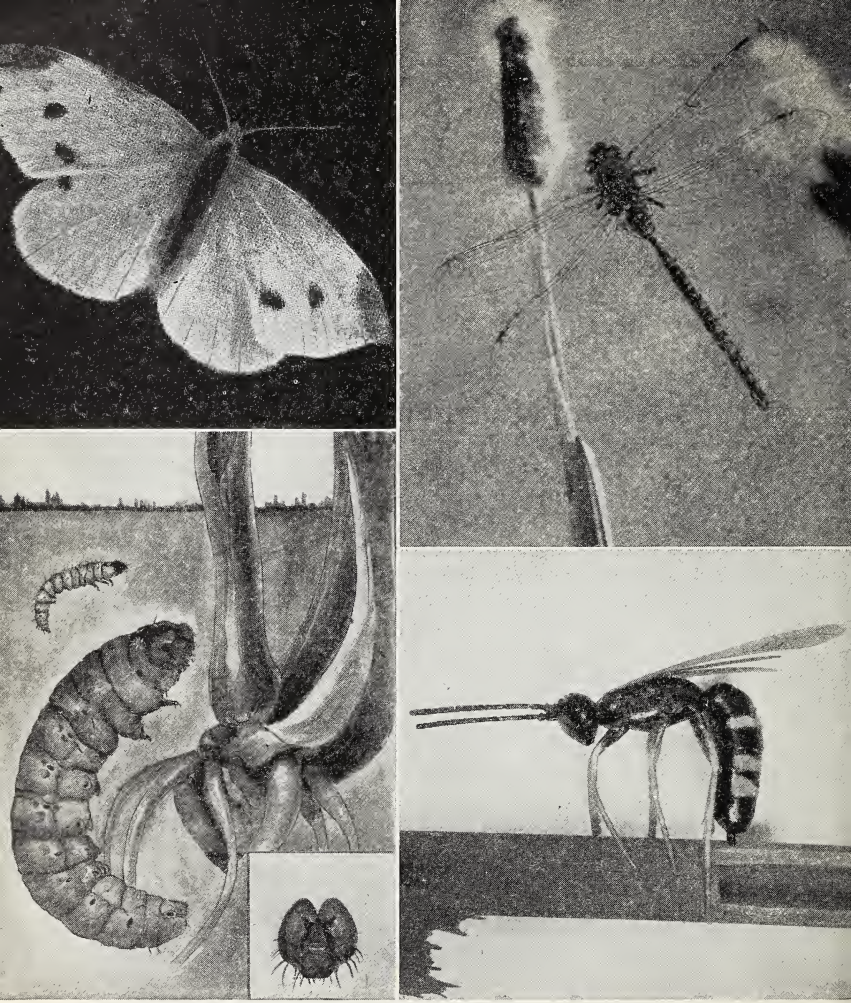
The only deadly poisonous spider in the United States is the black widow female, which is glossy black, with a red or orange hourglass marking on the underside. The tarantula bite is somewhat poisonous but not deadly. Many spiders can bite, injecting enough poison to cause painful swellings.

How are the insects specially adapted for survival? In some ways the insects are the world's outstanding specialists. They are better adapted for flying than are any other animals except birds. Some insects have the most highly developed social groups except those of man. Some insects are clever builders. Others are fierce fighters.

The insect differs from the spider and crustacean in several important ways. Its body is divided sharply into three parts: the head, the thorax, and the abdomen. A few insects have no wings. One large group, which includes flies and mosquitoes, has one pair of wings. Most insects have two pairs of wings. All insects have six legs, and have feelers, or antennae, on the head of adult forms.

The small size of insects is a distinct advantage, for they can hide easily, and require a relatively small supply of food. The tough skeleton and light weight of an insect makes flying at high speeds practical, for it does not dash itself apart upon landing.

Insects are able to produce large numbers of offspring, which is also an advantage. The average female insect probably lays about a hundred eggs, although some may lay many more than this. Insects may grow rapidly. A female housefly lays 150 eggs which develop into adult flies in two weeks. It is estimated that if all the descendants of a female plant louse lived, at the end of a single summer they would be numerous enough to form a chain around the world. Some insects in their development may go through four stages—egg, larva, pupa, and adult—while others grow through three stages—egg, nymph, and adult. Insects in the larva stage are special-



Courtesy Field Crop Insect Laboratory, Lethbridge, Alta.

Adult Insects of Alberta: *Top left,* Cabbage White Butterfly; *Top right,* Dragon Fly; *Bottom left,* Larva of Pale Western Cutworm; *Bottom right,* Female of wheat-stem sawfly laying egg in wheat stem.

ized for eating large amounts of food in order to grow rapidly. Many insects provide special care for their young.

Although the behavior of insects is not intelligent but instinctive, they are able to carry on activities of the most complex sort. The female mud-dauber wasp will catch and sting spiders until they are paralyzed, and put them into the nest with her eggs to provide her young with food. The helpless spiders cannot harm the young wasps, but because they are alive they do not decay or spoil. The young wasps are assured a supply of fresh food, although the mother never sees them. For when the female mud dauber has completed her task, she caps the egg cells over and leaves, never to return.

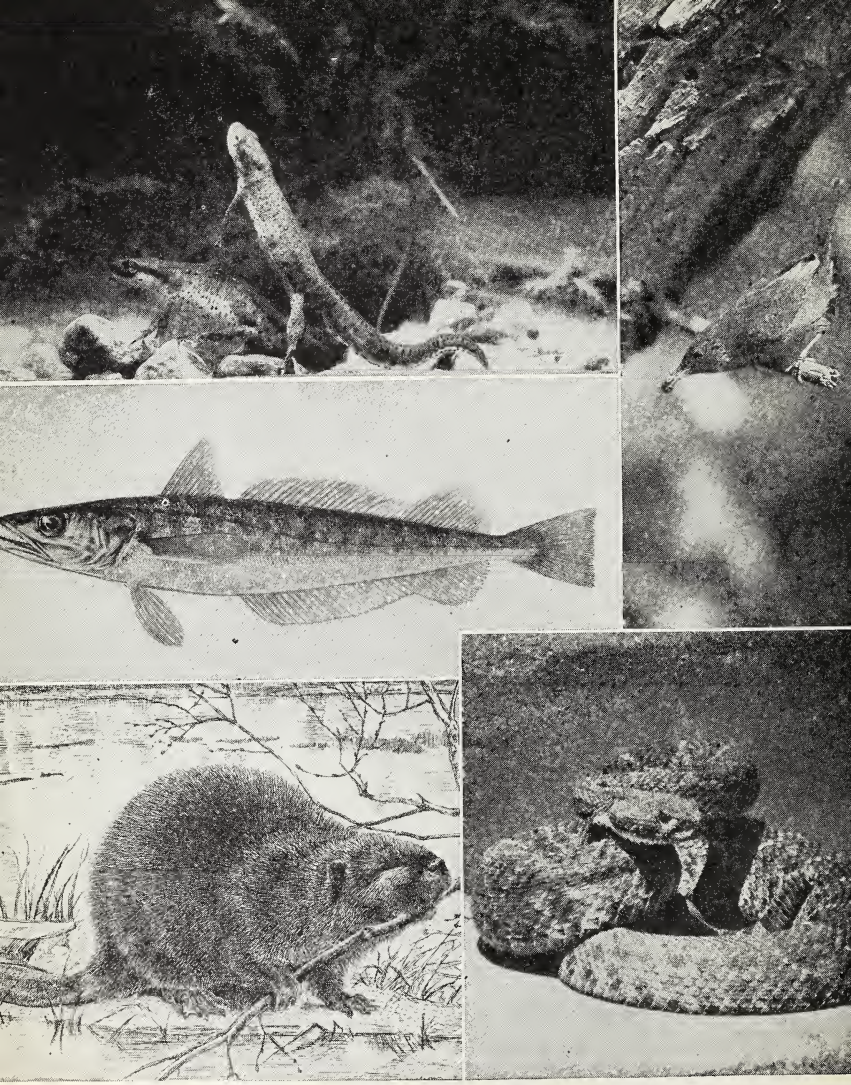
What are some other arthropods? The millipedes are commonly called thousand-legged worms, and the centipedes hundred-legged worms. Both are made up of many segments. The centipedes have one pair of jointed legs on each segment, while the millipedes have two pairs of legs on each segment. Only the centipedes have poison jaws. The millipedes eat vegetable matter, but the centipedes eat insects.

The ticks and mites are dangerous parasites that suck blood from poultry, game animals, farm animals, and human beings. In addition to being unpleasant and tending to weaken the animal on which they live by withdrawing blood from it, these parasites carry a number of dangerous diseases.

Exercise. *Complete the following sentences:* The animals which have jointed feet are called —1—. They have a —2— outside the body. The crayfish and crabs live in —3— and breathe by means of —4—. The spiders breathe by means of —5—. The bodies of —6— are divided into three parts. —7— have eight legs while —8— have six. The only arthropods with wings are —9—. The —10— stage of insects is especially adapted for food-getting. The —11— include the lobsters, crabs, and crayfish.

Science activities. 1) Introduce into the school aquarium some crustaceans which you find in ponds or streams. Study them.

2) Make a collection of insects, classifying them according to orders. You will need to study an insect book to do this. Mount them in a cigar box by pinning them through the thorax. Insects may be killed by dropping them into rubbing alcohol.



Left, center and bottom, U. S. Fish and Wildlife Service; top left, Hugh Spencer photo; top right, L. W. Brownell photo; and bottom right, Sharp and Dohme

These five animals represent the five large groups of vertebrates. The newts (*top left*) represent the amphibians; the whiting (*center left*) represents the fish; the beaver (*bottom left*) represents the mammals; the wren (*top right*) represents the birds; and the rattlesnake (*bottom right*) represents the reptiles.

3. How are animals with backbones fitted for survival?

Most of the common animals are those with backbones. They are classified together in a group called the vertebrates. Three of the five classes in this group are cold-blooded, and two are warm-blooded. The cold-blooded animals—the fishes, reptiles, and amphibians—are not really cold-blooded, but instead have the same temperature as the surroundings. Their blood may be warm or cold, depending upon the weather. The warm-blooded animals always maintain the same temperature, which for most animals is about 100 degrees Fahrenheit. Birds ordinarily have higher temperatures than do mammals.

All vertebrates have skeletons inside the body, with the backbone serving as the main structure upon which the body is built. Most vertebrates have four appendages—wings, legs, arms, flippers, or fins. A well-developed head is characteristic. In the head are the brain and special sense organs of hearing and sight.

What kind of animals are fish? The fish are vertebrates which live in water and breathe by means of gills. They are usually covered with scales, and their limbs are in the form of fins. Most fish have an air bladder, which is a sac found in the upper part of the body. The bladder can be made larger or smaller to keep the density of the fish about the same as that of water. Changing the size of the bladder permits the fish to rise or sink. The bodies of fish are streamlined for easy motion through the water. The tail is the chief organ of locomotion, for the other fins are used chiefly for balancing.

What animals lead a double life? Because frogs and toads live part of their lives in water and part on land, they are given a class name, amphibian [ăm·fĭb'ĭ·ăn], which means double life. Other amphibians are lizard-like in appearance, and include the newts and salamanders. The amphibians develop in water, and during the early stages of their lives breathe by means of gills. In their adult stages they live on land, although they usually remain near water. The adults have lungs and a heart, consisting of three chambers. Except for a few tropical species, they all have four legs. They never

have scales. The mud puppies and salamanders have tails, while the frogs and toads do not.

Frogs and toads have short front legs, adapted to support their bodies, and long hind legs, used for leaping on land and swimming in water. The toes of frogs are webbed.

Frogs usually live in or near water, but toads may live anywhere on land, returning to the water only to lay eggs. The frog feeds in the daytime, but the toad feeds at night. Both eat insects which are caught by a long, sticky tongue fastened at the front of the mouth. The frog has teeth in the upper jaw, but the toad has none. The frog has a smooth skin, while the toad has a rough skin.

The males of both frogs and toads can croak. Most amphibian songs are given when the animals are at the water to lay eggs, although the tree frogs trill in the branches of trees all summer. The sounds are produced when air passes forcibly back and forth between the lungs and mouth and over the vocal cords. Air in the mouth is held in sound sacs located either on the side of the head or under the throat. These sacs expand greatly when filled with air.

What kinds of animals are the reptiles? Some of the reptiles are quite familiar. The snakes, turtles, lizards, crocodiles, and alligators are known at least by reputation to most of us. Reptiles are covered either with scales or with horny plates. They always breathe by means of lungs. When they have toes, the toes have claws. The reptiles on the earth today are not important compared to the giant reptiles of millions of years ago. In those days some could fly, some were huge and fierce land animals, and some lived in water. But reptiles could not adapt themselves to the changing environment, and few remain today.

A lizard has a long body supported upon four legs nearly equal in size, and generally has a brittle tail which is easily broken off. Some familiar lizards are the horned toad; the chameleon [kȧ·mē′lē·ŭn], which can change its color; and the Gila [hē′lȧ] monster. With the exception of the Gila monster, lizards are chiefly harmless, and are of value because they eat insects.

The snakes are the only land vertebrates which have no legs. Their ribs and the scales on their bodies permit them

to move forward on rough surfaces at a considerable speed. Except for a few poisonous varieties, snakes are beneficial animals, for they eat insects for food. The stories you hear about snakes milking cows, breathing poison, charming birds, and rolling like hoops are purely superstitions.

The turtles are protected by their hard shells, and as a result are slow-moving and awkward. Some turtles are vicious and for this reason should be treated with respect. Turtles have no teeth, but bite by means of a horny jaw.

Courtesy Dept. of Travel & Publicity

The moose is a typical Alberta animal found in wooded and swampy areas.

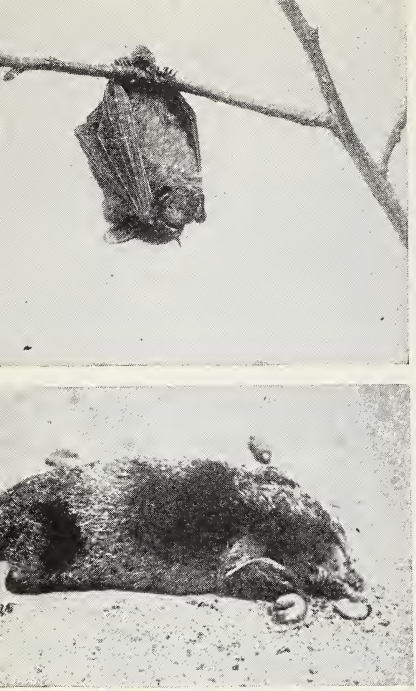
The head of the crocodile is longer and more pointed at the snout than is that of the alligator, which has a broad head rounded at the snout. Otherwise they are rather similar in appearance and habits.

Most reptiles lay eggs, but a few bear their young alive.

What sort of animals are birds? Birds are animals with feathers. The legs of birds are scaly. The forelimbs are developed into wings which are used for flight by most birds.

The power of flight makes birds different in their habits from other animals. They can range over a larger area for food, and can protect themselves by escaping from their enemies. Their easy means of movement permits them to feed on the ground and to nest in trees. Flight makes possible the migration of birds, which makes them less dependent upon adaptation to cold than are the other vertebrates.

Some birds, however, are adapted to live throughout the year in one locality. These resident birds depend upon types of food available in winter as well as in summer. We see some birds which come north in summer, other birds which come south in winter, and still others only when they migrate in the spring or fall. Most of the familiar, insect-eating birds



© General Biological Supply House

The bat and the mole both look somewhat like mice, but neither is a mouse. Bats catch insects in the air. Moles live underground and eat grubs.

are summer birds. The English sparrow, a seed-eating bird, is a resident bird, for it stays throughout the year. The Arctic tern is the champion traveler, for it migrates almost from pole to pole.

The beaks of birds are adapted in various ways to getting food. Modern birds do not have teeth, although some ancient birds did. The mouth opens into a food tube which widens out into a crop in which food is stored. The stomach of common pigeons and of some other birds consists of two parts: one of which secretes a digestive fluid, the other of which is a muscular gizzard filled with small pebbles used for grinding the food. Digestion is completed in the intestines.

All birds develop from eggs. Eggs commonly are incubated or kept warm by the female bird, although this is by no means always true.

What special adaptations have the mammals? The mammals are unusual in many ways. They include the most intelligent animals. Mammals are the only animals which have hair, and the only animals which produce milk to nourish the young. The young of most mammals are born alive and, in general, require the type of care which can be given by an animal of a fairly high degree of intelligence. Man, of course, is the highest type of mammal.

The variety of adaptations of mammals is rather amazing. The bats are adapted to flight, while the porpoises and whales are adapted to a life in water. Most mammals, however, are land animals.

The mammals which carry their young in pouches include the kangaroos and the opossums.

The animals which have claws include three very important groups—the meat eaters, the bats, and the rodents. Meat eaters have sharp teeth, small digestive systems, and are powerfully muscled for their size. Dogs, cats, bears, and weasels are typical of the meat eaters. The rodents include the gnawing animals with chisel-like teeth. The common rodents are squirrels, rats and mice, beavers, and rabbits.

The primates have nails instead of claws, and include monkeys and apes.

Another large group of mammals includes those animals with hoofs—pigs, deer, sheep, horses, oxen, and elephants.

You can readily see that these animals are adapted to different types of lives according to their structures. Claws are not so well adapted for running long distances as are hoofs. Hoofs are of little value for digging or for climbing trees. There are equally important differences in teeth, digestive systems, methods of adapting to warm and cold weather, and other matters essential for survival.

Exercise. *Complete the following sentences:* Fish, reptiles, and amphibians are —1— blooded. Animals with scales are —2— or —3—. Most vertebrates reproduce by means of —4—, the exception being the —5—, most of which bear their young alive. Animals with hair are —6—. Most vertebrates have four —7—. The only vertebrates with true wings are —8—. Turtles are members of the group called —9—. The word —10— means double life.

Science activities. 1) If a model of a dissected frog, fish, or rabbit is available, study its internal structure, and compare it with that of the honeybee.

2) When an animal such as a chicken or a rabbit is being prepared for the table, observe the internal organs, and identify as many as you can.

3) Make a zoo booklet, classifying animals according to groups listed in this problem.

Ring-necked Pheasants. Crich photograph.

UNIT TWO

HOW ARE LIVING THINGS ADAPTED FOR SURVIVAL?

ON A June day a man was sitting in his study in a town in New Hampshire. As he sat there, a chimney swift fell into the room through a hole in the chimney. The man picked up the bird and carefully fastened to its leg a tiny aluminum band with a number stamped on it. He then set the bird free.

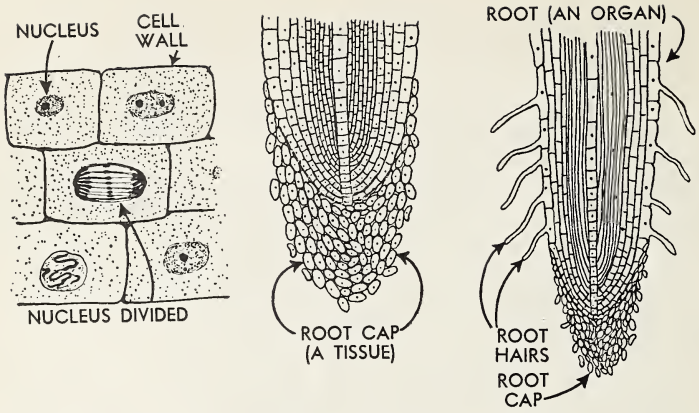
A year later as he was sitting in the same room, a swift again fell down the chimney. He picked up the bird and discovered to his surprise that it was the same bird that he had banded the year before. This bird had traveled to its winter home in South America and had returned after its long journey to the exact spot where it had made its home the year before.

The migration of birds is but one of the many types of adaptations of living things which help them to survive. The problems of survival are complex and difficult. Animals must not only eat, but must escape being eaten. For large animals such as lions this is not as difficult a problem as it is for smaller animals such as rabbits and grasshoppers.

Animals must produce their young and care for them in order that the race or species can survive, and at the same time must protect themselves. Some animals will die fighting for their young, while others will leave the young uncared for to defend themselves. Some birds make beautiful nests, while others lay their eggs on bare rocks. The oriole nest is a down-lined, deep basket. The nighthawk nest is a depression in the pebbles of a rocky hillside. Yet each of these birds manages to rear its young in spite of difference in methods.

Every living thing must find its place in the environment for which it is adapted. For most organisms this is not an easy task, for there are so many living things that they must constantly compete for food, living space, and other needed things to enable them to live.

These problems of survival are but a few that living things must meet. Can you name a dozen animals that are extinct today because they did not solve the problems of survival? Can you tell why they became extinct, while smaller and weaker animals were able to survive? Can you look at your own hands and see how they help you to survive? What would you do if you had paws instead?



All life processes take place in the cells. The cells are in various stages of division and growth (*left*). The root cap (*center*) is a tissue made up of cells. The entire root, including all its parts, is an organ.

1. What is life?

Most of us do not have much experience with plants and animals, nor do we have means of studying living things too small to see with our unaided eyes. As a result we are likely to think of life only in connection with people, the large, four-footed animals, the fishes and birds, a few reptiles, and perhaps a few insects. We find that our experience with plants is confined almost entirely to a few common seed plants.

Yet no matter how limited our observations may be, we note immediately the difference between living and nonliving things. In living things certain processes go on that do not take place in nonliving things. These processes taken together make up the complex process called life.

Life is obviously a process involving use of energy. Yet releasing this energy does not seem to reduce the size of the living organism, as a fire reduces the fuel on which it feeds. Nor do life processes come to an end unless energy is supplied from an outside source, as water ceases to boil when removed from the fire. Life is a process that continues of itself under certain favorable conditions.

What is the stuff of life? If you could add to your obser-

vation of common animals hundreds of thousands of observations of every imaginable living thing, you would have little need for changing your basic understanding of what life is. It is a series of changes that go on in a watery, jelly-like, fibrous chemical substance called protoplasm [prō′tō·plăz'm]. For protoplasm is the stuff of life, whether it is found in cabbages or kings.

The simplest living things are mere droplets of protoplasm which seem barely thick enough to cling together in the water in which they live.

While protoplasm exists in very primitive forms, it usually is organized into cells, tissues, and organs, each adapted to perform specialized functions.

Of what parts are all complex organisms composed? A real understanding of life processes could hardly have developed without the microscope, for the basic building block of complex organisms is the microscopic cell. Cells were discovered nearly 300 years ago (in 1665) by Robert Hooke. But it was not until about 100 years ago that it was recognized that all living things are made of cells.

A cell usually consists of three or more parts. Around the outside there is usually a cell wall, which may be made of one of several materials. Some microscopic sea plants, or diatoms, make cell walls of lime and other rocklike materials. The cell walls of woody plants are made of cellulose, a material from which cellophane is made. Other cells may have walls of materials less familiar than these.

Inside the cell is the protoplasm, which constantly streams about. A central part of the cell is called the nucleus [nū′klē·ŭs]. It is thicker in appearance than the other protoplasm, and seems to be the point from which growth and cell division begin.

In any animal containing more than one cell we are likely to find groups of cells similar to each other in appearance and function. These cell groups are called tissues. The lining of the mouth, the material of bark, and the groups of muscle fibers which permit animals to move are all tissues. Each tissue has some special function to perform in carrying on the life processes of the organism.

Groups of tissues which work together are called organs.

L. W. Brownell photo

Many animals change as they grow. This snake has grown a new skin beneath the old one and has shed the old skin.

Roots, leaves, eyes, claws, feathers, stings, and stomachs are organs.

What activities are necessary for life to exist? You already know that there are many functions necessary to make life possible. Among these are the ability to get food and air, the ability to move, and the ability to adapt to the environment. These life functions are closely tied up with certain properties or abilities of protoplasm.

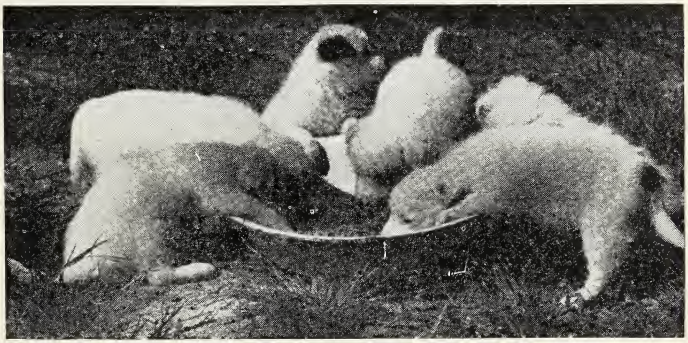
The whole process of using food and releasing energy from it within the organism is metabolism [mĕ·tăb′o·lĭz′m]. Metabolism consists of two different types of activity. One of these is a building or constructive process; the other is a tearing down or destructive process. The constructive process is commonly carried on by plants when they make food, and is carried on to some extent in the bodies of animals, as when cows produce milk. The constructive process also takes place in the cells where new protoplasm is built.

The destructive type of metabolism releases energy. This ability to release energy from food is common to all living

things. Bacteria causing decay of an apple, a plant turning its leaves to follow the sun, and a tiger following its prey through the jungle are all using energy. The bacteria cannot make their own food, but instead absorb and use up the foods on which they grow. In the process they release heat, carbon dioxide, and water. They may also release other materials, depending upon the nature of the food they are using for their growth and activities.

The plant turning to follow the sun uses energy as truly as does an animal, and as a result also releases heat, carbon dioxide, and water from the food stored in its stem and leaves. The tiger requires a much more complex type of food than do the bacteria and plants, and as a result of using its food releases energy in more complex ways and produces more complex wastes. Yet from the body of the tiger heat is released and carbon dioxide and water are given off, as well as more complex wastes containing minerals and proteins (chemicals containing nitrogen).

A second property of protoplasm is irritability—the ability to respond to a stimulus. The stimulus in the case of the plant is sunlight, and the response is a turning movement. The stimulus of the creeping tiger is hunger from within, and a complex combination of sights, sounds, and odors that seem to promise food. Every large muscle cell of the tiger's body



Courtesy U. S. Bureau of Animal Industry

These pups are busy taking in food in order to change it to protoplasm. Without food they could not grow up to become big dogs.

responds to direction or stimulus of the nervous system to make possible the quiet, powerful movements necessary to follow a wild deer through dense thickets.

A third property of protoplasm is its ability to move. You know already that protoplasm constantly streams and flows within the cell, and that most living animals can move about to some extent. These movements, motion and locomotion, are essential for continued life.

A fourth property of protoplasm is growth. This process is closely related to metabolism, for until the building process provides sufficient material to increase the size of the organism growth is impossible. You have already learned how many living things grow—how the chick hatches from the egg, how the fly maggot changes from a wormlike animal into a fly. Growth results from an increase in the amount of protoplasm within an organism, and from a reorganization of the protoplasm to form new cells and tissues. Sometimes entire new organs are produced, as is the case when the fly develops wings in its pupa stage.

A fifth life process of protoplasm is the ability to reproduce. In the beginning stages of reproduction, living things are amazingly similar. For no matter how large or small an organism may eventually be, all start from the growth and division of a single cell. In the case of bacteria the cell divides into two bacteria, and reproduction is complete when the cells carry on their life processes separately. In the case of a higher plant or animal—a carrot or a sparrow—the division of the cell starts a most complex series of developments, which finally produces a large organism made up of perhaps billions of cells all working together.

Exercise. *Complete the following sentences:* —1— is a series of changes that take place in a substance called —2—. The simplest living things are composed of one —3—. In more complex organisms the cells work together to form —4— and —5—. —6— is the process of building up and destroying protoplasm. Wastes formed by the destructive process almost always include —7—, —8—, and —9—. —10— is the ability of protoplasm to respond to a stimulus. Increase in size or change in organization of protoplasm is —11—. All life starts from one —12—. The central part of the cell is the —13—.

2. What characteristic of life makes it able to continue?

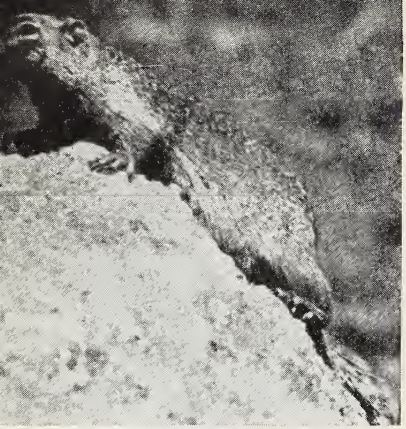
This brown bear, like all bears, hibernates in the winter. It is adapted to live in forest regions.

It would seem that in the great variety of soils, climates, and moisture conditions which are found on the earth, some places would be so poorly adapted for life that no living things could possibly survive. Yet in desert places we find the mesquite, a low shrub, slowly working its roots as far as 50 feet through the parched soil for a tiny trickle of life-giving water. On the bare rocks of a mountain, where it would seem that no life could exist, we find growing a dry, scalelike plant—a lichen [lī′kĕn].

In the frozen wastes, a red tint on the snow indicates the presence of algae—another simple plant. Even the ocean is filled with countless millions of floating organisms, some widely scattered and others tangled so close together that they actually retard the movement of ships. To live in all these different surroundings and to withstand the different conditions calls for different types of adaptations.

What is adaptation? Adaptations are the structures and types of behavior which enable an organism to continue to live under certain conditions. Some living things perish because they are not able to adapt themselves to a changing environment, while those that can adapt themselves survive.

The environment includes all those things and forces in the midst of which an organism lives. Some of the factors in the environment are living things—other plants and animals—



L. W. Brownell photo

This ground squirrel is found in rocky regions of the West. It eats grasses and seeds and lives in a burrow.

while other parts are nonliving. The living environment contains factors both helpful and harmful to an organism. All living things depend upon other living things, dead or alive, for food or for materials from which to make food.

How does structure determine how organisms live? Every living thing is adapted to a single, rather limited type of environment. The structure of the organism—the way it is built—determines what this environment is.

The environment of the grizzly bear is the Rocky Mountains. The bear fits into this special environment in many ways. First of all the bear is a mammal, which makes it necessary to live where it can breathe by means of lungs. It is a meat-eating animal, but adds to its diet a limited amount of nuts and wild fruits. The grizzly is specially adapted for digging, for its powerful, slightly curved claws may be three inches in length. The grizzly uses these claws to turn stones over and to tear up rotten logs in search of insects and grubs. The bear digs ground squirrels from their burrows. But the grizzly bear does not always limit his food to these small forms. It is so powerful that it can and does kill large animals, including deer and cattle, by seizing them and breaking their necks. The grizzly bear has a shaggy coat of white-tipped brown or black hairs which enables it to hide among rocks by blending into the background.

In the same environment in which the grizzly bear lives is found the ground squirrel. The ground squirrel also has claws well adapted for digging, and lives in burrows which it digs in loose, rocky soil. Its food consists of seeds, fruits, field crops, and occasionally insects and small animals. Its fur is brown and mottled in color, making it blend into the color of the rocks and dry soil in which it lives.

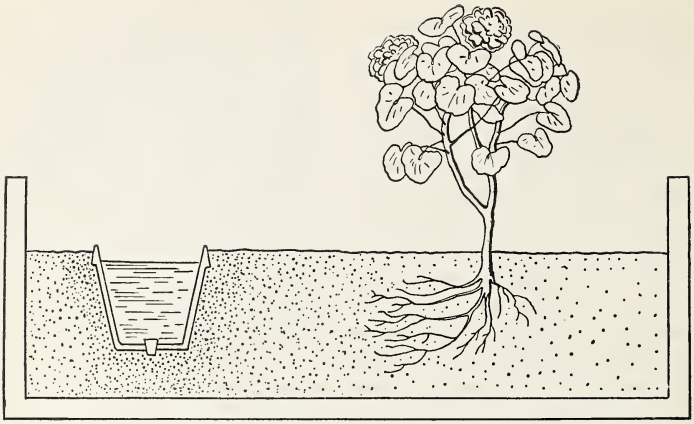
It may appear at first that the ground squirrel and the grizzly have the same environments. In many respects they do. Yet their structures make these environments different in many respects. The grizzly does not need to hide from any enemy except man, while the ground squirrel can protect himself only by staying near enough to his burrow to dive into it when threatened by larger animals—hawks, coyotes, and bears. The grizzly need not consider these factors in the environment, for his great size and strength enable him to travel in safety where he wishes.

The flesh-tearing teeth of the bear and the gnawing teeth of the ground squirrel determine to a large degree the kinds of food each can eat. Their digestive systems differ in size and in the kinds of chemicals they secrete to digest food.

When greatly differing animals are compared, it is still easier to see how structure determines the environment in which the organism lives. A canvasback duck may live on a mountain pond in the region where the bear and ground squirrel live, yet its structure causes it to live an entirely different life. Its webbed feet make it unfit for land, but well fitted for swimming. Its oiled feathers make it able to float on the water. These ducks are so much at home in water that they dive to a depth of several feet to obtain the water plants that root in the bottom of shallow ponds and lakes. The beaks of ducks are broad and scoop-shaped, and are provided with a comblike filter along the edges from which water runs from the food. The nest is always located as near water as is possible, and is hidden among reeds where the gray-brown feathers of the female make concealment possible.

When we compare the structures of warm-blooded animals with those of frogs, snakes, earthworms, oysters, and other cold-blooded animals, these differences become still more apparent.

Plants are as different from each other as are animals. To make a comparison that is easy to see, consider the differences between a water lily and a corn plant. The water lily has a thick, fleshy root from which comparatively few fibrous roots extend, for the struggle to find water and food is not a difficult one. The stems of water lilies are soft and weak. The



The seeking of water by growing roots is a tropism. The water is the stimulus, the increased rate of growth the response.

leaves are broad and flat, and they float on the water rather than being held up by the stem. The flowers are large and showy to attract insects which carry the pollen. The corn plant has a root system of thousands of fibrous roots which extend far into the soil; a hard, tough stem; and leaves which can roll up to reduce loss of moisture. The flowers are small and the pollen is carried by the wind.

How does behavior make animals fit their environments? There are four general types of behavior. The simplest is called a tropism [trō′pĭz'm]. The turning of the sunflower to the sun is such a form of behavior. Tropism in the simple, one-celled animal, the amoeba, is shown when it is touched with a bristle, and its protoplasm flows away to the side opposite the point of stimulus. The seeking of water by plant roots and of light by the leaves are tropisms. The upward growth of stems is also a tropism.

Among higher animals there are three types of behavior: reflex behavior, instinctive behavior, and intelligent behavior. A reflex is usually rather simple in nature, and it is not learned nor is it controlled by thought. The inner workings of the bodies of animals are largely reflexes, for the muscles which control digestion, breathing, getting rid of

wastes, and other life processes do their work without thought or direction. When you drop your cat wrong side up he quickly turns in the air to land on his feet. This is a rather complex type of reflex act.

All the complex acts of most animals are instinctive. Let us see how the instincts of the grizzly, ground squirrel, and duck adapt them for winter. In the Rockies it is too cold for most animals to live, and the snow is too deep for them to find food. The bear and the ground squirrel alike become possessed of great appetites, and eat until they are fat and sluggish. As winter approaches, they each go to a place to hibernate—the bear to a protected cave or hollow under rocks or to the roots of an upturned tree, the squirrel to his burrow. Then gradually they fall into deep sleep, and move as little as possible, until spring finds them restless, lean, and hungry.

The duck joins a flock of other ducks, and practices flying and landing to get into condition after a summer of living afloat on the water. Then on some cold morning the flock takes off and flies south to a warmer region.

You will note that behavior is dependent upon structure. The bear could not possibly fly south, nor could the duck hibernate. The steps that lead to hibernation must come in order, for unless the bear is fat he does not hibernate so early nor stay asleep so long.

In order to grow straight, plants have special structures. Grasses have joints at intervals along the stem. The tropism of growing upward is dependent upon the structure of these joints, for cells grow thicker on one side than on the other until the stem is fairly straight.

Does environment determine adaptations? The kind of adaptations an organism has depends upon two things: its ancestors and its surroundings. No organism has more to develop from than it inherits from its ancestors but, even so, organisms of the same kind differ from each other. Factors in the environment are more favorable to one individual than the other. When deer are chased by wolves, the fastest runners escape, while the slowest are caught. Over a long period of time—usually periods of thousands of years—most living things definitely change to fit their environments. It is only intelligent animals that are capable of making rapid changes,

and even in their case there is a limit to the amount of change that can be made in a short time.

Microscope slide: Algae.

Exercise. *Complete the following sentences:* —1— is a structure or change in an organism fitting it more perfectly to live in its —2—. Claws, wings, and teeth are —3— which help the animal to adapt to its environment. The simplest type of behavior is a —4—. Internal behavior of animals consists mostly of —5— acts. Migration and hibernation are examples of —6—, which are complex acts. Color of animals helps them to —7—. All living things depend upon others for —8—. The canvasback is a duck which obtains food by —9—. Two warm-blooded animals are —10— and —11—.

3. How are green plants fundamental to all life?

Survival of all life depends upon a sufficient supply of food. Yet there is only one source of food—the green plant. No matter how well adapted an animal may be or how good the environment in other respects, if there is not a sufficient supply of green plants to provide food, all other life ceases to exist.

Are all plants green? As you know, there are two types of plants: those which are not able to make food and those which are. The plants which cannot make food are not green. Strictly speaking, foodmaking is not limited entirely to green plants, for there are a few red, brown, or blue-green plants which can make food. The foodmaking plants which are not green are chiefly algae which live in the ocean. The simplest foodmakers are the simple green scums that grow in ponds and in the ocean, and they provide a food supply for many other simple living things.

How do green plants make food? The process of making food is a chemical change—that is, energy is taken in by the plant and is used to change one kind of material to another. The process by which food is made has a difficult name—photosynthesis [fō′tō·sĭn′thē·sĭs], which means "light (*photo*) put together (*synthesis*)."

In order to make food, the plant must have a supply of raw materials, there must be machinery or chemicals in the plant

to do the work, there must be a source of energy, and there must be some way to use the food and get rid of wastes.

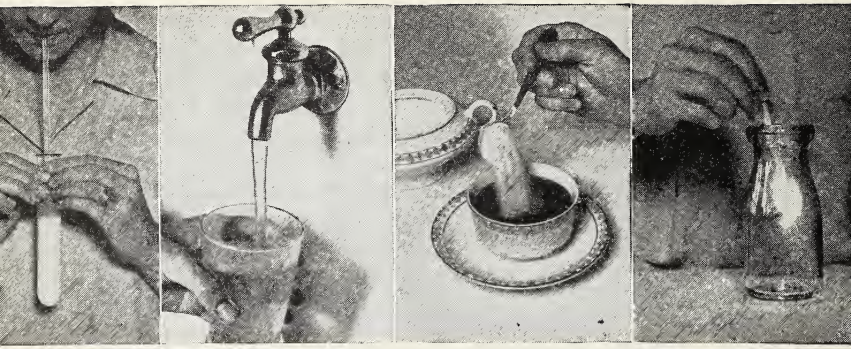
What raw materials are used in making food? The final product obtained as a result of photosynthesis is composed of the three elements carbon, oxygen, and hydrogen. The materials from which the leaf obtains these elements are water and carbon dioxide. The hydrogen is obtained from water, the carbon is derived from carbon dioxide, and the oxygen may be obtained from either water or carbon dioxide.

Water may be absorbed from the soil by tiny hairs on the roots of seed plants, or directly from water by water plants. The carbon dioxide usually has a much shorter journey to make. There is always a small amount of this gas in the air, and most pond and ocean water contains dissolved carbon dioxide. Seed plants take carbon dioxide in through openings in the leaf called stomates. Other plants absorb it directly.

What is chlorophyll? The actual work of making starch is done by the chlorophyll [klō′rō·fĭl], which gives the green color to the plant. Chlorophyll is found in the stems of some plants, as in the horsetails and cacti, and in the bark of many young plants. But from a practical point of making food, most of the work of photosynthesis is carried on in the leaves of larger plants. One-celled plants contain the chlorophyll within the cell.

What is the source of energy? The source of the energy used in making food is the sun. The sun is the source of our heat and of most of our light. It is this light that the chlorophyll needs to do its work. The leaf works from sunrise to sunset, and it is only during the hours of darkness that the chlorophyll rests. The length of the leaf's working day varies according to the latitude and the month. In the southern parts of Alberta during the longest days of the summer the leaf works from 14 to 16 hours a day.

Leaves can make food in artificial light as well as in sunlight. Experiments have been done to learn the effect on the growth of plants of increasing the number of hours they were kept in the light. Some plants were kept in the light 15 hours daily, some 20, and some were kept in the light all the time. It was found that the plants matured more quickly when kept in the light longer. But there was a limit beyond



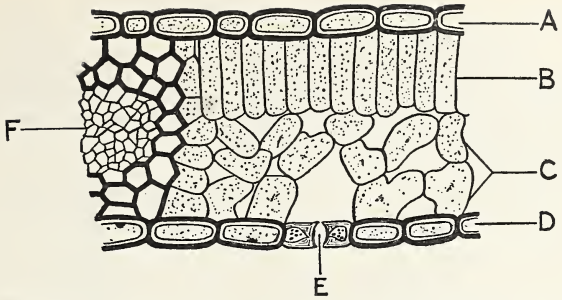
These four pictures show the chemicals taking part in the chemical change: carbon dioxide plus water yield sugar plus oxygen. Explain the tests.

which an increase in the hours of light did not further hasten the growth of the plants.

What product is formed? The products of photosynthesis are carbohydrates. They include both starch and sugar, which are found in the green plant. Probably the first product formed is sugar, which is then changed to starch. These two forms readily change one into the other. The carbohydrate is stored as starch, which is insoluble. The insoluble starch may be changed to a soluble sugar and, in this condition, carried in the sap to all parts of the plant. A square yard of leaf surface makes about three pounds of starch during the summer. In order to realize how much food plants make every year, one has only to think of the huge crops of corn, wheat, potatoes, apples, and foods of every kind that the farmers reap annually. All this food is but a tiny fraction of the food made by plants.

What by-product is formed? The primary function of chlorophyll is to form sugar. But in the process another material, the element oxygen, is given off. All living things and all fires are constantly using up the oxygen in the air. Through the process of photosynthesis, the supply of this valuable element is renewd.

How do plants make proteins? Plants make not only carbohydrates but also fats and proteins. In fact all the food



This cross section of a leaf shows the upper epidermis (**A**), the palisade cells (**B**), the spongy cells (**C**), the lower epidermis (**D**), the stomate (**E**), and the vein (**F**).

supply of the world is dependent on the activities of plants. Since protoplasm appears to be composed chiefly of proteins, the importance of proteins to plants as well as to animals is clear. Proteins contain the same three elements as do carbohydrates—carbon, hydrogen, and oxygen—but in addition they also contain nitrogen and some other elements, such as sulphur and phosphorus. The first three elements are obtained from starch; the other elements are obtained by the plants from minerals in the soil or in water.

The exact process of protein-making is not well understood; but some facts regarding it are known. Proteins are made from starch and mineral salts. Neither chlorophyll nor light is necessary for making protein.

How do plants get rid of water? While the seed plant is making food and giving off oxygen, it is also giving off excess water through the stomates of the leaf. This process is called transpiration [trăn′spĭ·rā′shŭn]. The amount of water thus given off is very large. An experiment carried on in Kansas showed that a corn plant lost nearly two barrels of water in a single season. This was nearly 100 times as much as the plant needed for all purposes except to replace that lost by transpiration. This large amount of water is needed to provide the small amount of mineral salts required by the plant.

As the water reaches the outer surface of the leaf, it evaporates and passes into the air as water vapor. The amount of water lost by transpiration varies greatly from day to day,

depending on such factors as the temperature and humidity of the air. Within certain limits the amount of water transpired is controlled by the guard cells of the stomate. Generally they are open during the day and closed at night. The stomates also tend to close during the day when the supply of water in the leaves is deficient.

Demonstration. Is There Starch in Green Leaves?

What to use: Green plant, alcohol, burner, beaker, iodine, pin, black paper.

What to do: On a large green leaf pin a smaller disk of black paper, and leave it for 24 hours. Set the plant in sunlight. Remove the leaf, take off the paper, and boil the leaf in water a few minutes. Dissolve out the chlorophyll in alcohol. With iodine, test the leaf for starch.

What was observed: Did the leaf turn dark blue all over? What does this color indicate?

What was learned: Is starch manufactured in the part of the leaf not exposed to sunlight?

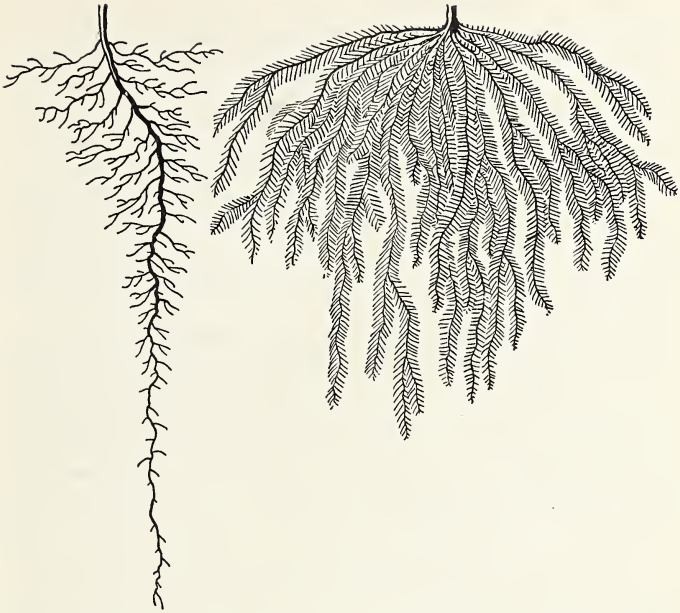
Microscope slide: Cross section and epidermis of leaf.

Exercise. *Complete the following sentences:* Starch is manufactured by green plants from water and —1—. Giving off water by the leaves of plants is called —2—. —3— is the process of making food. In the process of photosynthesis the gas —4— is given off. Proteins are made from starch and —5—. If a growing leaf is placed under a tumbler, —6— will collect on the inside of the tumbler. The energy needed by plants for manufacturing starch comes from the —7—. The green substance in the leaves is —8—. The process of —9— is the basis for the world's food supply. The small openings in the skin of the leaf are called —10—.

Science activity. Find in a reference book microscope views of leaves, and make a soap sculptured model showing a leaf greatly magnified. Put in the various cells, a vein, and stomates.

4. What are some adaptations which help plants make food?

In order to carry on the important function of making food, all plants have special adaptations. Of course the most important of these is the presence of chlorophyll. But other



There are two kinds of root systems common among seed plants. The taproot (*left*) grows downward from the center of the plant and other roots branch from it. Many fibrous roots grow from the base of the plant and spread in all directions.

adaptations are also necessary in order to provide light, mineral food, water, and carbon dioxide to the part of the plant which makes the food. Some sea plants are light enough to float on the surface where they can get light. Other plants root in the lake or ocean bottom and send up long stems to the surface to reach light. While each kind of plant has its own adaptations, it is the seed plants which have the most successful adaptations for getting the things needed for making food.

How do roots help the plant to make food? The root systems of most seed plants are quite extensive. If a small plant is carefully dug up so as to keep all the roots, it will often be found that this system is even larger than the part above ground. Alfalfa plants sometimes send their roots 20 feet deep

in the soil. To include all the roots of a single grass plant, it is necessary to wash away more than a cubic yard of soil.

There are two types of roots, the taproot and fibrous roots. A taproot consists of a single large branch that grows straight down, giving off smaller branches. A fibrous root is composed of many small branches of about the same size. The beet plant has a taproot, and the grass plant a fibrous root.

A root has three main regions. Covering the end of the root, like a thimble on a finger, is a root cap, which protects the tender parts beneath. Just back of this cap is the growing region of the root. The root does not grow in length in any other of its parts.

What causes absorption of water and minerals? The most important part of the root in absorbing water and minerals is the root hairs. They are found only near the growing tips of the young roots. As the roots grow longer, new root hairs appear just behind the tip, the older hairs meanwhile disappearing. They are very numerous, for there are sometimes as many as several thousand to an inch. Each hair is a tiny, hollow tube with a wall so thin that soil water can pass through it. The root hairs cling closely to the particles of soil and increase greatly the surface used for absorbing water.

The process by which the water passes through the walls of the root hairs is known as osmosis [ŏs·mō′sĭs]. The walls of the root hairs act as membranes. The water in the soil is less dense than the cell sap, which contains sugar and other dissolved materials. Under these conditions the water passes from the less dense to the denser liquid. That is, water from the soil passes through the wall of the root hair into the cell sap. The pressure of osmosis forces water upward through the root which serves to carry water to the stem of the plant.

How do roots anchor the plant? In order that a plant may stay where it can obtain a supply of water, it must be anchored in the soil with its root hairs in close contact with soil particles. Roots serve as anchors and foundations of the plant by developing a rigid structure and by wrapping themselves closely around soil particles. Corn plants have roots which serve as braces to support the stem. Almost every plant has some adaptation whereby its roots serve to support the stem.

How does the stem help to make food? The stem has two important functions in foodmaking. It must serve as a transportation system, and it must either support the leaves or itself carry on the foodmaking process. There are two types of stems common to seed plants.

Trees and many other plants have stems with the parts arranged in rings. The outer layer is the bark, the inner layer the woody part, and the part between is the cambium [kăm′ bĭ·ŭm]. The cambium is made up of a layer of cells from which growth proceeds. The inner part of stems more than a year old is really dead, but serves the important function of strengthening the plant. The newly formed wood carries the water and dissolved minerals from the roots to the leaves, while the newly formed bark carries food from the leaves to the roots.

Another type of stem is represented by the corn plant and other grasses. The bundles of tubes which carry water and food are scattered throughout the stem, and in each bundle some tubes carry water up the stem and other tubes carry food down the stem. As seen under the microscope, the larger tubes are the ones which carry water.

For holding the leaves to the light there are many interesting adaptations. The trees grow so tall that they rise above other plants. Some low plants branch in all directions in order to expose the leaves to light as much as possible. Certain plants develop as vines which climb and twine around any support which can be used to hold leaves to light. The grapevine has special stems called tendrils which twist around the support. The leaf stalk of the nasturtium twists around a support to hold up the plant. The bindweed stem produces tendrils which entwine themselves by means of spiralled curls to the support on which the vine is climbing.

The stem of the cactus plant actually makes the food. The leaves are developed as spines and do not contain chlorophyll.

A few plants have stems which grow underground and send up branches at intervals in search of a suitable place for growth. One of the most common of these is quack grass, a plant which is very successful in competing for food and light with other plants. The potato is an underground stem used for storage of food and for providing a place for buds

The stem of the bean plant twines around a support to lift the leaves toward the light. Find a grape, a garden pea, and an English ivy to compare with the bean as to their manner of climbing.

to develop for growth a year after the potato was formed.

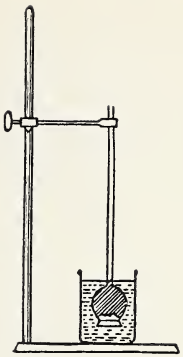
How do leaves help in making food? The leaf is generally the food factory of the plant. In order to reach the light, leaves are provided with petioles [pĕt'ĭ·ōl, leaf stalks] which twist in such a way that the flat part of the leaf—the blade—is turned toward the light. The leaf has a complete system for circulating water and food. This system consists of the veins, which are made up of the same kinds of bundles of tubes as are found in stems. The veins of grasses and related plants are parallel, while the veins of many other plants are arranged to form a network.

What tropisms help the plant to make food? Most of the tropisms of plants are concerned with making food. The turning of the leaf on its stalk to reach light is such a type of behavior. You recall of course that roots grow toward water. This tropism is of utmost importance for the survival of the plant. The tendency of roots, under the influence of gravity, to grow downward and of stems to grow upward is also essential for the success of the plant in making food. The opening and closing of the stomate by the guard cells is another tropism essential to conserving moisture when the plant is becoming dry, as is the rolling of the corn leaf.

Demonstration. What Is Osmosis?

What to use: Thistle tube, pig bladder, sugar, rubber band, beaker, ring stand, stopper.

What to do: Put the stem of the thistle tube in the stopper. Fill the funnel end of the thistle tube with thick sirup, holding a finger over the small end to keep the tube full of air. Put the pig bladder or a sausage casing over the large end of the tube. The sirup should rise in the stem about an inch. Put the large end of the thistle tube in a beaker of water, with the level of the water and of the sirup the same. Support the tube on the ring stand, as shown in the diagram, by holding the stopper with a clamp.



What was observed: Can you see that the water has risen in the tube at the end of an hour? At the end of 24 hours?

What was learned: What happens in the process of osmosis?

Microscope slide: Cross section of root.

Exercise. *Write a paragraph summarizing this problem, using in it the following words:* root hairs, osmosis, wood, bark, bundles of tubes, cambium, minerals, water, sirup, stomate, light, food, tropism.

Science activity. Put different kinds of roots and stems, such as willow twigs, potatoes, carrots, and geranium stems, into colored ink. Let them stand overnight, and cut into the stems or roots to see how far the liquid has risen.

5. How are different plants adapted for survival?

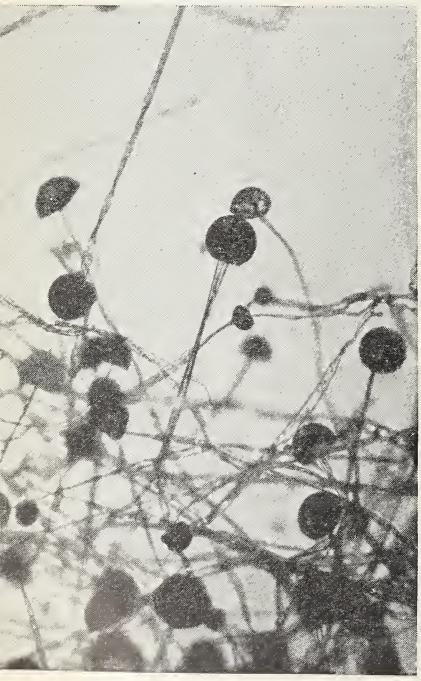
There are many kinds of plants upon the earth, each different in structure and adaptations from all other kinds. Yet in spite of the minor differences between plants, they still are adapted in general to carry on their life processes in similar ways. All plants of each large group solve the problem of reproduction in a similar way: one group by cell division, another by development from spores, and another by growth from seeds. Because of these fundamental similarities, we can best study plants by learning to place them in groups where they naturally fit.

What are the adaptations of the simplest of plants? There are two distinct types of simple plants. One type, the algae, is capable of manufacturing its own food. The other type,

Hugh Spencer photo

The algae above are made up of similar green cells which grow in chains. The bread mold below is threadlike, taking its food from the bread. The black circles are spore containers.

Hugh Spencer photo



the fungi, obtains its food from either living or dead materials.

The algae may live in either fresh or salt water. Some grow on the trunks of trees. The pond scum seen growing in masses in ponds is composed of a great many algae plants. When examined under a microscope, this mass is found to consist of slender threads, each made of similar cells joined end to end. The algae occur in a variety of colors—green, red, and brown. The Red Sea gets its color from the algae living there. Brown and red algae which can live in hot water give color to the mammoth hot springs in Yellowstone Park. Many algae are composed of but a single cell.

Fungi have no chlorophyll. If they use living matter as food, they are called parasites [păr′*ȧ*·sīts]. If they attach themselves to dead matter, they are called saprophytes [săp′rō·fīts]. Some of the fungi that take food from living plants are the cause of plant diseases. Rust on wheat and blights and mildews on other plants are examples. Bacteria and yeasts are very common fungi.

Mushrooms or toadstools are the only fungi recognized

by most people. The common distinction between mushrooms and toadstools is that the former are safe to eat, while the latter are poisonous. But to a botanist the two words mean the same thing. Some of the nonpoisonous forms look very much like the poisonous varieties, and these cannot be told apart except by experts. Generally it is not safe to pick your own mushrooms for eating.

The part of the mushroom which we see above the ground is only the reproductive part. Below the ground are rootlike parts which absorb the food from things on which they grow. This is a useful adaptation for the environment. The parts underground are located where the food supply is. And since they cannot make their own food, they have no need for light. Location of the reproductive part above the ground makes it easier for the spores to be spread.

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This poisonous fly mushroom is typical of the most commonly known group of fungi. The portion seen above ground produces spores.

Mushrooms occur in a great variety of shapes. One of the most common is the umbrella shape. The top part is called the cap. On the underside of the cap are found gills in some plants and holes in others. If the cap of these gill mushrooms is cut from the stem and placed gills down on a piece of paper, the spores will drop out to make a spore print. The lines of this spore print are arranged like the spokes of a wheel. The spores, however, differ in color. They may be black, white, pink, or brown.

Puffballs are another common form of mushrooms. When they are ripe they are filled with millions of tiny spores, which puff out as a powder when the puffball is squeezed.

This group, including both fungi and algae, which generally is called thallus [thăl'ŭs] plants, contains in all about 80,000 different kinds of simple plants.

What are the mosses? The mosses are more complex in their adaptations than thallus plants. They do not need to live either in or close to water. However, they are rarely found in extremely dry regions. The plants are not more than a few inches high. They may be found on the ground, on rocks, or on tree trunks. All of this group are green and are therefore able to manufacture their own food.

They have stems and leaves but no flowers. Their system of reproduction is more advanced than that of the thallus plants. The moss reproduces in a complex way by developing through two stages. One stage produces a plant which develops the egg and sperm [spûrm, that part which is needed by the egg to help it grow]. From this plant there grows a second plant which produces the spores which are then scattered.

The mosses are generally unimportant. One kind, accumulating over long periods of time, forms peat bogs. Because the bog mosses absorb large quantities of water, they are much used as packing materials for living plants.

What are ferns? Did you ever see a "fiddlehead"? This name is often given to the opening buds of ferns. Instead of opening as do the buds of trees, they unroll upward from the inside. On these buds you can find a fine plant down. Some birds use this down to line their nests.

In the spring new fern leaves grow outward from the old plant, leaving the central area without leaves. This circular arrangement of new fronds is sometimes called a fairy ring.

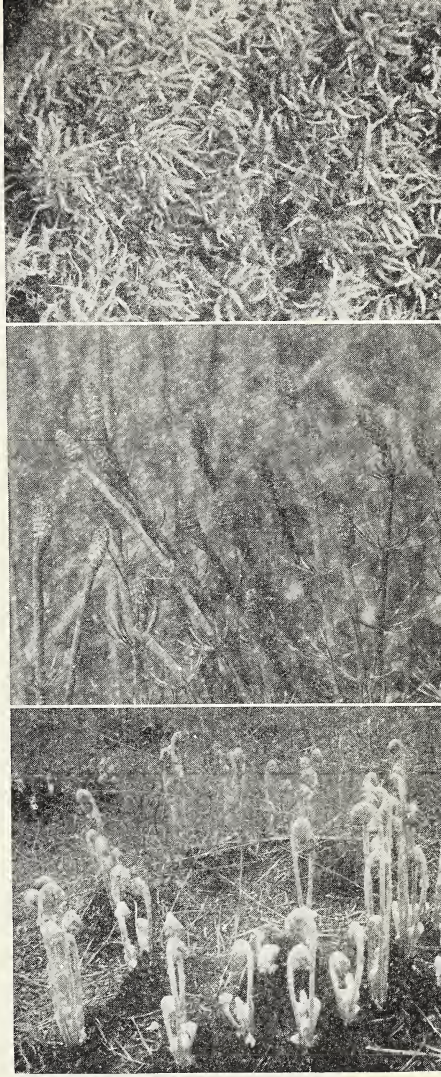
The part of the fern plant that you most commonly see is the leaf, also called a frond [frŏnd]. The leaves are generally divided into smaller parts, each part looking like a separate leaf. The stems are generally found underground, although in the tropics the main trunk may extend as much as 10 to 50 feet above the ground. At the top of this trunk is attached

a mass of great leaves which may be as much as 20 feet long. Most ferns grow only in shaded positions, commonly being found in moist woodlands or shaded ravines. The horsetails are weedy plants related to the ferns. They usually grow in thin, moist soil.

Fossils found in coal beds show that millions of years ago these plants grew to be the size of trees. Our coal beds were formed from the remains of these ancient fern forests.

What are seed plants? Because they are well adapted to their environment, there are more kinds of seed plants than all the other kinds of plants combined. These are the only plants that reproduce by means of seeds. Since the flower is the organ which produces seeds, all of these plants possess some sort of flower and develop some kind of fruit. They have well developed roots and stems. The method of branching and form of leaf are important means of identifying the different members of the seed plants.

Seed plants bear their seeds in one of two ways. Most of the evergreens, such as the pines and spruce, bear their



L. W. Brownell photos

Top, the type of moss that grows in swamps; center, horsetails showing spore containers; bottom, ferns in the "fiddlehead stage."

seeds in cones and are therefore called conifers [kō′nĭ·fẽrz]. The second group of seed plants produce their seeds inside of some seed container. The seeds of some of these plants have a single seed leaf, while other seeds have two seed leaves, and still others have many seed leaves. Corn, wheat, lilies, and tulips produce seeds having only one seed leaf. The common trees, shrubs, vines, and most of the plants of the vegetable garden produce seeds having two seed leaves. The big trees, or giant sequoias [sẽ·kwoi′ȧs], of California produce seeds having many seed leaves.

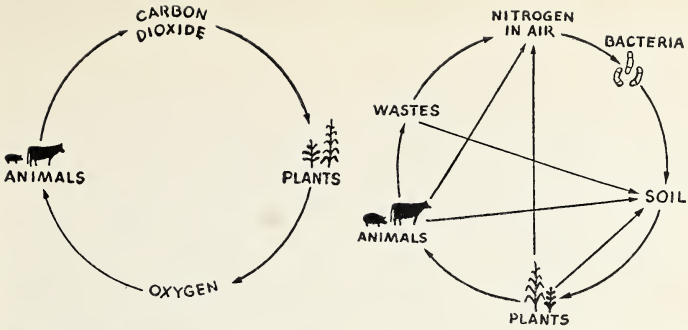
How may plants be classified? The plant groups just described are classified as they are because all members of a given group are similar in structure. The present system of plant classification was developed by Linnaeus [lĭ·nē′ŭs] during the eighteenth century, and the methods of classification which the botanist uses today follow his suggestions.

Thus we see that there are four large groups of plants: seed plants, ferns, mosses, and thallus plants. Within each of these groups the plants are further subdivided into smaller classes and these, in turn, into still smaller groups. Sometimes the classifications of the scientist are surprising to us, because we are likely to classify plants on the basis of their use rather than their structures. Thus, to us the rose is a flower and an apple is a fruit, but to a botanist they are both members of a very closely related group.

Slides (2x2 inch): The great groups of plants—MK02. Chicago Apparatus Co.

Exercise. *Make a table by ruling your paper into four columns. Head the columns as follows:* THALLUS PLANTS, FERNS, MOSSES, SEED PLANTS. *In the correct column write the following words:* algae, bacteria, corn, petunia, yeast, hollyhock, horsetails, peony, molds, mushroom, elm tree, rock moss, Boston fern.

Science activity. Make a collection of plants, trying to get two examples of each of the three simple types of plants and 10 seed plants. Most plants can be pressed and kept dry. Label each plant according to the type to which it belongs. Some dried plants may be kept from shattering if dipped in paraffin. Plants may be kept in cellophane envelopes.



The carbon and oxygen cycle (*left*) is much simpler than the nitrogen cycle. To help you understand the nitrogen cycle, look at the animals. Arrows indicate that they give off nitrogen through wastes and that when they die they give off nitrogen to the air or to the soil. Can you explain each arrow?

6. How do living things depend upon each other?

In our everyday observation we have learned that living things do not exist alone nor separately in the neatly classified groups which we have just studied. In any community of living things there are many different kinds of plants and animals, each depending in many ways upon other organisms. Some animals depend upon plants for food, some upon other animals. In less obvious but just as important ways plants also depend upon animals for their food. Then too, maintaining the supply of air required by living things is dependent upon the different needs of plants and animals for gases in the atmosphere.

How is the supply of carbon and oxygen kept in circulation? In the relatively thin layers of soil and water and in the limited amounts of air in which living things must exist, there is but a small supply of materials necessary to maintain life. While we often think of the supply of oxygen and carbon dioxide in the air as limitless for practical needs, this idea is in error. Even the gases in the air are not free, but must be kept available by the work of living things.

You are familiar with the process by which plants make food. Carbon dioxide is absorbed from the air, and water is absorbed from the soil. In the process of photosynthesis, oxygen is released and passes out into the air. The carbon is stored in the various kinds of foods and structures of the plant.

When an animal eats food, the food is oxidized in its cells. As a result of this oxidation, the oxygen is no longer free but is combined with carbon. The carbon is thus released by animals from the plant and becomes part of the air.

The plant also uses some of its food to release energy, which keeps its protoplasm in motion and makes its tropisms possible. In the process some of the stored food is oxidized, and carbon dioxide is released. Bacteria which cause decay also release the carbon stored in plants, for one of the products of decay is carbon dioxide. About the only carbon which is permanently stored by living things is found in limestone and other similar rocks and in coal. All other carbon is kept in circulation.

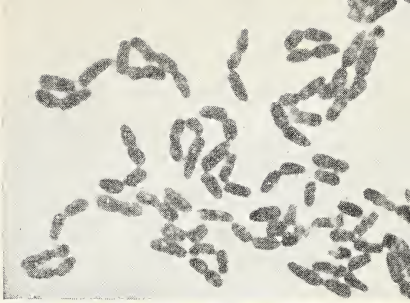
The supply of carbon dioxide in the air is so small that this constant renewal is important. It would not take many millions of years to use up the entire available supply if it could not be used over and over again in this way.

The changes just described are called the carbon dioxide-oxygen cycle, and may be represented by a circle as shown in the diagram on the opposite page.

How do living things use nitrogen? There is an abundant supply of free nitrogen in the air, but this nitrogen is of no use to the common plants and animals. They must take it directly or indirectly from the soil. There are few ways in which the supply of soil nitrogen is kept up. Some nitrogen is combined with oxygen in the air as a result of lightning discharges, and the resulting gas dissolves in rain water and enters the soil.

But the most important source of nitrogen from the air is that fixed in the soil by bacteria. These simple bacteria often live on the roots of the legumes—beans, peas, clovers, alfalfa, and locust trees—where they receive certain foods from the plants, and in return provide the supply of nitrogen so essential to this group of plants. Other nitrogen-fixing or nitrifying bacteria may live in the soil without the aid of the legumes.

The only source of protein foods (foods containing nitrogen) available to animals is plants. Although animals make more complex compounds of nitrogen than do plants, they still must obtain the raw materials indirectly from the soil.



© General Biological Supply House

These are some of the bacteria which live in the soil and fix nitrogen from the air in salts which are useful to green plants.

The nitrogen used by animals is returned to the soil in two ways. The animals give off nitrogen in their body wastes. These wastes enrich the soil to an important extent. Farmers recognize this fact when they use barnyard manure for fertilizer. Then when the animals die their bodies decompose, forming certain nitrogen compounds, and some of the materials thus formed enter the soil. But because nitrogen compounds are easily dissolved in water, the supply may be washed out of the soil. Then too, there are certain bacteria which break up the nitrogen compounds formed by animals and permit the nitrogen to pass back into the air. When plants die, the nitrogen they contain may similarly be released—either to the soil or the air.

The nitrogen cycle is much more complex than is the carbon dioxide-oxygen cycle. But it is just as important for life.

How do plants dwell together for mutual aid? If you are a good observer, you have noted the gray-green patches on rocks which are called lichens. Until about 50 years ago it was thought that they were single plants, but use of the microscope shows that they are colonies of algae and fungi living together. The fungi seem to absorb moisture which they release to the algae. The algae make food, some of which is used by the fungi. Both members of the partnership seem to be benefited, for the lichens grow where neither algae nor fungi can survive alone.

How do some animals live together for mutual aid? You are familiar with the complex social life of the bees and wasps. It is an interesting fact that many social insects belong to one order. In this order are also the ants. The ants have colonies in which all work together—some providing food, some caring for young, and some acting as soldiers.

Certain species of ants cannot do any work except fighting.

These ants capture other ants which are generally considered to be slaves. These slaves do the work of providing food and caring for the nest. Some soldier ants are so helpless that they cannot even feed themselves. Another group of ants cares for aphids, which give off honeydew. The ants of one species carry to the roots of corn plants the aphids which suck juices from the roots, injuring the plants. This removal of the juices may reduce the yield of corn and interfere with the food supply of animals which eat corn—man and his domesticated animals.

A story credited to Darwin and Huxley shows how many circumstances may be involved in one situation. Red-clover flowers are so deep that only bumblebees can pollinate them. But if there are many field mice about, the clover is not pollinated, for the mice eat the bumblebees by raiding their nests. However, if there are enough old maids in the community who own cats, the cats will eat the mice, thus insuring a good crop of clover seed.

Cheap seed increases the amount of clover planted, and causes a drop in the price of beef because there is plenty of clover to feed to cattle.

Are all relationships mutually helpful? You know that many bacteria are dependent upon living things for food. These parasites usually do nothing in return for the food they take, and if they are too numerous they may kill the plant or animal upon which they grow.

Saprophytes are somewhat useful, for they cause the release of carbon dioxide from dead plants which are keeping carbon out of circulation. Although saprophytes do cause food to spoil and useful materials to decay, nevertheless, in the whole community of living things, their work is essential for life to continue. For it must be remembered that no living thing owns the material of which it is made. Rather, it has merely borrowed the material for use, and must return it if life is to continue.

Exercise. *Write a paragraph summarizing this problem, using in it the following words:* carbon dioxide, oxygen, nitrogen, air, legumes, manures, animals, plants, bacteria, food, decay, nitrifying. *Illustrate your paragraph by drawing in your notebook the two cycles discussed in this problem.*

Science activity. Set up as individual projects as many fresh-water aquaria as you can, using a variety of water plants and animals. In some, use fish; in others, insects; in others, crayfish; in still others, clams or leeches. Try to find a supply of plants which will live with the animals and provide them with oxygen. Do not forget that algae will provide considerable amounts of oxygen.

7. Why is there a constant struggle for survival?

You know already that any species of living things can produce many more offspring than can possibly survive. An interesting problem that you can work out for yourself is to figure how many offspring a pair of rats may produce in three years. Assume that all the young live, that half are males and that half are females, that the average litter numbers 10 young, and that the first young are born when the rats are six months old. Rats may bear four litters a year.

What is overproduction? One of the important means by which a species of any living thing maintains itself is by its ability to produce many offspring. Some common weeds bear thousands of seeds. A single plant may produce seeds enough to cover a city lot with plants if all the seeds grew. Insects produce hundreds of eggs. Even the mammals can produce many young. One cow may have six to ten calves in her lifetime. A pheasant hen lays perhaps 20 eggs every year. The female fresh-water perch (a fish) lays 100,000 eggs each spawning season. Practically every living thing is similarly capable of producing more offspring than can survive.

Because there is overproduction of all living things, they crowd and compete with one another in many ways. The most serious problem, of course, is that of finding a supply of food. Plants require a certain amount of space for their roots, and from the soil they take the water and minerals available. Soil simply does not contain enough minerals and water to support an unlimited number of plants. And in places where the soil is thin and dry, the amount available for plants is decidedly limited.

Even where the soil is rich and moist, there may exist such serious overcrowding of plants that there is not enough light to permit all plants to grow vigorously. Of the many seeds

Ewing Galloway photo

It may seem that lions kill because they are cruel. But the lion indirectly improves the animals on which it preys by eating those which are less able to escape. The lion kills, of course, to obtain food.

that may germinate, many will die before they mature because they are overshadowed by more vigorous or better-adapted competing plants.

There is a similar overcrowding of animals. If in a given area all the rats born as offspring of one pair should survive, the resulting rat population would soon overrun the land. In some tropical islands rats have been introduced by accident where they had no enemies to keep them in check. First the rats ate the best food available—birds' eggs, young, tender plants, and shellfish that they found at low tide. The lack of birds gave insects an opportunity to multiply, and the amount of plant growth was decreased. As the rats became more numerous, they began to eat the larger plants. The larger animals died from lack of food, and the rats ate their bodies. Finally the rats ate everything that was fit to eat, and turned

on each other. They soon starved, and the soil eroded. What once was a pleasant land at last became desolate waste.

This illustration is but slightly more extreme than many others that might be chosen. The importation of rabbits in Australia caused a large part of the continent to be overrun by the pests. Hundreds of thousands of dollars are spent in fighting them annually—by building rabbit-proof fences and by poisoning them. Foxes were introduced to help control the rabbits, but the new environment proved so favorable for the foxes that they became large and fierce enough to kill and eat sheep. Watercress, which is a harmless plant in England, choked streams until boats could not navigate them in Australia.

In Bohemia, a state of middle Europe, four Canadian muskrats were introduced. There they increased in number and size until they are now pests. They dig tunnels in dams and banks of ponds, which are used for growing fish. They eat river crabs and mussels (a mollusk used for food by man). They go onto the land to eat grain and vegetables.

These examples are but a few of the many that show what happens when the balance of nature is upset by overproduction. Natural conditions eventually restore any upset of balance in one of several ways.

How is a natural balance maintained? Under natural conditions every living thing has its enemies. These enemies may be larger animals or they may be parasites and disease bacteria.

The smaller animals—the rodents, the birds, and even the insects—are kept in check because they provide food for larger animals. Whenever their number increases, they provide an increased supply of food for the animals which naturally eat them. These animals, called predators, increase in number and reduce the population of small animals.

Another important factor in reducing numbers is disease. When animals are few in number, they stay far enough apart that the probability of infection is decreased. But when they live crowded together, the ticks, mites, and lice which carry disease can more easily pass from one animal to another. The catching of disease by direct contact is also more probable when animals are crowded. The increase in number of

Courtesy National Association of Audubon Societies

Not all living things are adapted to changing environments. This famous picture of the passenger pigeon shows these beautiful birds as they were painted long ago by Audubon. Today there is not a living passenger pigeon in the world.

grouse, rabbits, and some other small animals proceeds in a regular manner, until finally they become seriously overcrowded. Then within a single year the population will drop to less than one-tenth of what it was. This change in the number of small animals is so regular in occurrence that game wardens can predict it quite accurately in some sections of the country.

A third and perhaps most important factor limiting the number of survivors is the lack of food. When deer become too crowded in a forest, they eat leaves from trees and shrubs

as far as they can reach. Young deer, or fawns, are unable to reach enough leaves for food when they no longer take their mothers' milk. They either die or grow up lacking in strength and vitality.

A fourth factor in keeping down populations is rate of reproduction. Only healthy and well-fed animals reproduce at a normal rate. When disease and a decreasing food supply reduce vitality, fewer young are produced, and the species tends to decline in number. This rule has been tested experimentally on fruit flies (sometimes called vinegar gnats) and is observed to apply to rats and domestic cattle.

What is "survival of the fittest"? Among all types of animals there are differences of many kinds. These differences between individuals of the same species are called *variations.* Some animals are stronger than others, some more able to resist disease, some more capable of finding food, some more clever in escaping enemies. Some plants are able to send their roots deeper into the soil, some to climb higher to reach light, some to produce thicker foliage to shade competing plants.

In any given environment some individuals are better fitted to survive than others as a result of these variations. As is natural, these are the individuals that produce the most offspring and, as a result, their qualities are passed on to their offspring. Over a long period of time considerable changes may take place in a species. For example, all wild horses in the western United States are descendants of horses brought by the Spaniards. These horses were Arabian stock —tall, slender, and swift. But as a result of selection, their descendants are shorter, stockier, and tougher in ability to withstand cold and lack of food. The Indian pony weighs several hundred pounds less than its Arabian ancestors.

This natural selection of individuals results eventually in survival of the fittest.

Exercise. *Make a table by ruling your paper into four columns. Head the columns as follows:* PLANT OR ANIMAL, NATURAL FOOD, NATURAL ENEMIES, USUAL ENVIRONMENT. *Using all information you can find in this entire unit, complete the table by listing 15 animals and 10 plants in the first column, and other information in the other columns.*

Science activities. 1) In a large, flat box put sand in one corner, sawdust in another, soil in another, and stones in another. Count out 100 radish seeds and scatter them over the box. Keep the box moistened, and at the end of a week and of two weeks count the number of surviving plants.

2) In a flowerpot filled with rich soil put bean seeds as thick as they will lie in a single layer, and cover them with a half-inch of soil. Keep them watered well, and observe what happens. Keep a record of the number of seeds used, and the number of plants surviving.

8. How are living things protected from their enemies?

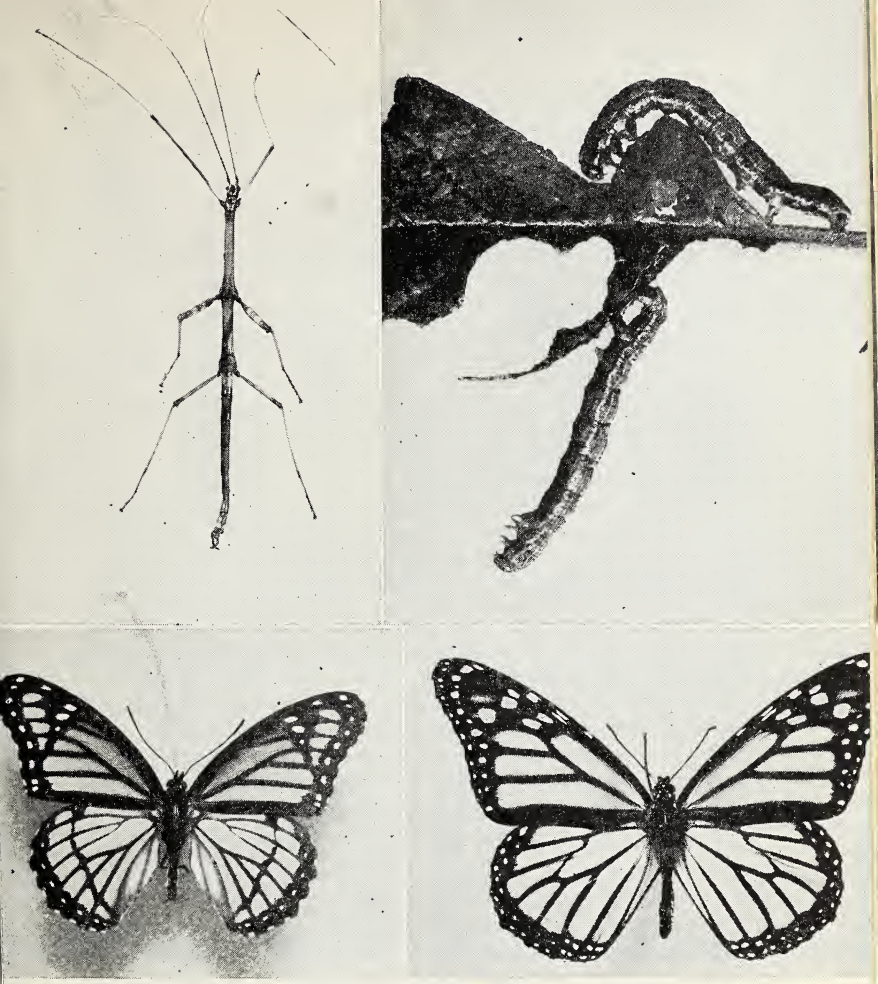
Since every living organism must eat, most living things are in constant danger of being eaten. For the enemies of most living things are those other living things which depend upon them for food. Other enemies are chiefly those which compete for the same food—that is, a jackal and a hyena may want to eat the carcass of the same zebra after it has been left by a lion. If the jackal and hyena fight, it is to obtain food. Animals may also fight to obtain mates. Queen bees fight for the right to live in the colony.

Plants and animals are protected by special structures or by special behavior or by both.

How does color protect animals? Some animals are colored so much like their surroundings that it is difficult to see them. Most birds are rather dull colored, darker above than beneath, with the color along the sides shading from dark above to light below. This is called counter shading. The same type of coloration is seen in fish, for many fish are dark olive color above and whitish beneath. When fish are seen from above, they look like the bottom of the stream or lake; but when seen from below, they blend into the white light from above.

The walking stick is an insect that resembles its surroundings not only in color but in shape as well. It has long, slender legs and feelers, and looks so much like a twig that the difference is difficult to see. The walking stick remains motionless most of the time. It is a relative of the grasshopper.

Some animals imitate other animals or part of a plant in



Courtesy U. S. Bureau of Entomology and Plant Quarantine

Three of these four animals—the walking stick (*top left*), the measuring worm (*top right*), and the viceroy butterfly (*bottom left*)—are fakes, seeming to be that which they are not. The monarch butterfly (without bars on the wings) is protected by bad taste. An animal which has learned by experience not to eat the monarch will not eat the viceroy. But if the wings of the viceroy are removed, the animal will then eat it.

color or shape. This type of imitation is called mimicry. Many flies mimic bees or wasps, which are well defended by their stings. Some beetles and moths are also similar to wasps in appearance, which is confusing to their natural enemies, besides making it difficult for us to distinguish them.

The monarch butterfly is distasteful to birds, and is not eaten by them. But the viceroy butterfly does not have an objectionable taste. The viceroy is so similar in appearance to the monarch that birds often fail to eat the viceroy because they mistake it for the monarch. The dead-leaf butterfly looks much like a dead leaf when at rest. Its wing veining mimics the veining of leaves, the edges of the wings look like the margins of leaves, and there are even two transparent spots which give the appearance of holes eaten in the leaf by insects.

Some animals change color with the seasons. In the far north the fur of many animals is white in winter, but becomes brown in the summer. The hare, fox, lemming, and weasel blend with the white snow in winter and with the brown earth in the summer because they grow two coats of fur a year. Similarly the ptarmigan [tär′mĭ·găn, a bird which lives high in the Rocky Mountains], changes its color with the seasons.

The chameleon can change its color quickly. Its surroundings and its state of rest or excitement cause the change. This animal, which naturally lives in the tropics, may be bright green or grayish brown. One kind of chameleon is a favorite animal for a pet. Many of them are sold at circuses and fairs.

How are colors used for warning? There are some animals which have no need for concealment, for other animals know from experience that they are unpleasant or disagreeable or dangerous. Many caterpillars which have a disagreeable taste are brightly colored, apparently to serve as a warning to birds to avoid them. Another conspicuously marked animal is the skunk, for the white stripes down the back contrast sharply with the black fur. The skunk is well protected by the disagreeable odor of the liquid which it gives off when in danger of attack.

The conspicuous color of wasps serves the same purpose. The only protection these insects need is to make their presence known, for few animals care to risk their vicious sting.

How are other animals protected from their enemies? There are many methods of defense used by animals against their enemies. The stings of the wasps, bees, and bumblebees are hollow tubes, needle sharp, which are used when necessary to inject a poison into the flesh of the enemy. The honeybee can sting only once, but the bumblebee and wasp can sting again and again.

L. W. Brownell photo

The Gila [hē′ lä] monster is the only poisonous lizard in the United States. Its skin looks as if it were made of brilliant beadwork, serving as a warning coloration.

Four snakes commonly found in the United States are poisonous. These are the rattlesnake, the copperhead, the moccasin, and the coral snake. The fangs of these snakes are hollow and, as they strike, pressure upon the poison sacs causes the poison to be injected into the wound caused by the bite. The bites of these snakes are frequently fatal.

The catfish or horned pout possesses sharp spines capable of inflicting a severe wound on any enemy attacking it.

The porcupine is covered with sharp, barbed quills, which come out easily. When attacked by an enemy, it rolls up into a ball. If an enemy is so rash as to attack this ball, its mouth is pierced by the quills which work their way into the flesh. Porcupines cannot shoot out their quills at the enemy.

Some fish can give an electric shock to enemies attacking them. In this group are found the torpedo, the electric catfish, the electric eel, and the stargazer. The torpedo has on each side of the head a large structure which serves as a battery to give a shock when touched.

Other animals have a hard external shell which protects the soft parts within. Turtles can withdraw the greater part of their heads and legs within their shells. The armadillo, which lives in the South, is a mammal which is provided with bony movable shields. When disturbed, it rolls up into a ball, exposing these hard shields on every side.

Courtesy U. S. Fish and Wildlife Service

The snapping turtle has two effective defenses: a hard shell and the ability to bite viciously. Its disposition matches its ugly appearance.

Some animals pretend to be dead when attacked by their enemies. They remain quiet until an opportunity of escaping presents itself. This kind of behavior is so typical of the opossum found in the southern states that the expression "playing possum" has become a part of our language. The hog-nosed snake, which lives in sandy places east of the Rocky Mountains, also pretends death as a means of protection.

Of a somewhat similar nature are the means taken by the ruffed grouse to protect its young. The nest is located on the ground. When an enemy approaches the nest, the mother pretends to have a broken wing, and drags herself a little way ahead of the enemy. When it has been led to a safe distance from the nest, the mother suddenly flies away.

What other means of protection do animals have? You know that many animals can fight so well that they have little need of other defense. Tigers, eagles, and weasels are rarely attacked by enemies. Other animals which are practically without means of defense are so clever at fleeing that they need not fight. Most birds can flee their enemies. The sparrow flies quickly out of reach of the cat; the pheasant runs from the fox; and the duck swims away from the hungry wolf. In fact flight is a means of defense almost as common as concealment.

How are plants protected? Plants as well as animals have ways of protecting themselves. The chief enemies of plants are animals and such unfavorable weather conditions as ex-

treme heat and cold and drought. The bark of trees and shrubs with its tough layer of cork keeps the rain from the stem and prevents evaporation. Plants are protected from animals by prickles and thorns, as is the case of the cactus and thistles. Some plants have a disagreeable taste or odor which protects them from being eaten by animals. Some plants are poisonous.

Exercise. *Complete the following sentences:* Turtles are protected by a —1—. Wasps possess —2— as a means of protection. Counter —3— is a kind of protective resemblance. Resemblance of one animal to another for protective purposes is called —4—. The walking stick resembles a twig in both color and —5—. During the winter the color of the ptarmigan is —6—. The —7— is able to change its color quickly. The white stripes on the skunk are examples of —8— colors. The rattlesnake can eject a deadly —9— through its fangs. The cactus plant has very small —10—.

Science activity. Paint two potatoes almost white on one side, blending the paint so that it gradually fades into brown, leaving one half wholly brown. Use another unpainted potato for comparison. Run stiff wires through all three potatoes. Put the light side of one painted potato underneath, and the light side of the other painted potato above. Place all three in a bare spot. Support them by sticking the wires in the soil, and observe them from a distance.

9. How do plants and animals live together in communities?

A community of living things is found in a region of sufficient size to support many forms of life, and consisting of the same conditions of soil, moisture, and climate throughout its area. One type of community may blend into another, and some animals may live at times in more than one community. Within a community the relationship of the various organisms is close. If the community exists for more than a few months, there must be a fairly good balance of plants and animals.

What is a typical forest community? A typical forest community of the eastern slope of the Alberta Rockies

L. W. Brownell photo

The lynx, or bobcat, is a common dweller of the northern forests. It eats a variety of small animals. It looks somewhat like a large housecat except for the hairs on its ears.

is complex in its make-up. The most conspicuous part of the community, of course, is the trees, and this is the only part the careless observer sees. The typical forest may contain many different combinations of trees, depending upon soil and moisture conditions. But there are usually spruce, pine, fir, poplar and birch trees in an upland forest. Sometimes junipers or willows are found. Growing partly in the shade are shrubs of many kinds, one of the interesting ones being the saskatoon, which bears fruit. There is a variety of low-growing plants, some of which bear attractive flowers.

The more common flowering plants include the fireweed, tiger lily, lady's slipper, wood violets, Indian paint brush, and the wild bluebell. Some flowering plants bear berries in the autumn, a few of the commoner ones being the wild strawberry, blueberry and the huckleberry. In the shady places where a moist, sandy soil is found there may be ferns of various kinds.

When one has observed all life on the surface of the soil he still has not come to the end of living things, for the soil

contains millions of bacteria—perhaps as many as a billion per gallon of soil. Worms and insect larva abound in the rich humus soil of the forest.

The animal life of the forest is not easy to discover, for most animals are shy and protected by keen ears and noses. There are many members of the squirrel family in the forest. Red and gray squirrels live there, but not in the same neighborhood.

Along the edge of the forest may be found the chipmunks. These lively, striped animals live in burrows but come out during the daytime in search of food. They eat spruce cones and pine nuts and seeds of grass and ragweed plants. They may eat wild strawberries in the summer and rose hips in the autumn. They sometimes turn to a meat diet consisting of grubs of beetles, frogs, and small snakes. Occasionally they eat the eggs of birds.

Many mice live in forests, depending upon weed seeds, nuts, maple seeds, and insects for food. They store seeds for use during the winter, choosing a hollow in the ground or in a log for a hiding place for their food.

The insects of the forest are of several varieties, the commonest being beetles of various kinds, wasps and bees, some varieties of ants, and a few species of butterflies and moths.

The birds of the forest can be heard but are not easy to see. There are always woodpeckers and jays in forests. Woodpeckers drill beneath the bark for insects, while Canada jays pick insects from the leaves and bark. The flicker is a woodpecker that scratches among the leaves to find beetles and ants. Other birds which may be seen by the watchful observer are the humming birds, goldfinches, kingbirds and the bush partridge. Among the birds of prey are the hawks and owls, which eat small animals—mice, squirrels, and chipmunks. The magpies eat mice, birds and insects but they are also a nuisance to farmers because they destroy young chickens.

Ranging the woods are the larger mammals. The deer eat the leaves of shrubs and trees. Preying upon the rabbits, deer, and other larger animals are the foxes and wolves. The foxes eat birds, reptiles, and fruit, as well as small mammals. And occasionally there ambles into the woodland

L. W. Brownell photo

The flowers of the pitcher plant grow from the cluster of pitcher-shaped leaves at the base. Explain how each leaf serves as a trap for insects.

scene a brown bear, depending upon fruits, insects, and small animals if nothing better is found, but taking deer if they are available.

What is a typical orchard community? Compared to the natural forest community, the man-made orchard community is simple. The fruit trees and the clovers and grasses growing beneath the trees make up most of the plants. The bees pollinate the flowers in the spring and take the nectar to make honey for food. The clovers provide nectar later in the season.

There will naturally be a number of insect-eating birds in the orchard. But man simplifies the environment of the orchard still further by use of poisonous sprays which kill many of the insects which would naturally live on the leaves and fruit of the trees. If left alone, codling moths survive to

lay their eggs in apple blossoms; tent caterpillars spin their webs on the leaves and devour them; and many other insects —flies, ants, wasps, and butterflies—make their homes among the trees and grasses.

What is a typical swamp and bog community? A swamp is a region in which areas of spongy land and open water are more or less intermixed; while a bog is more likely to be made up of little elevations called hummocks, and more often than not is shaded by occasional trees. Common trees growing in bogs are tamaracks and black ashes. The lower-growing plants in both places are grasses and sedges, which grow with their roots in the water or in the rich soil just above the water line. The soil of swamps and bogs is largely formed from decaying vegetation and silt washed in by rains. This soil is saturated with water. Growing on the hummocks are found many beautiful flowers, but they are often almost buried from sight by the competing grasses. The marsh marigold, the wild calla, the duckweed, the violet, and the skunk cabbage are commonly found near or in bogs. Out in the shallow water of the swamp grow the familiar cattails.

In some parts of central and northern Alberta, the boggy ground is called "muskeg." This land is not suitable for farming purposes unless it is drained. Even when drained, it has a spongy texture which makes soil-working exceedingly difficult. In the summer-time, it is often quite common to find ice a few inches below the surface of this mossy material. Here was a kind of natural refrigerator which existed a long time before man adapted it to his use. Near Edmonton, Alberta, certain muskeg areas are being drained and the dried-out spongy material is pressed into a cake-like mass and used for insulation in homes and is called MOSS-TEX.

The birds of bog and swamplands are numerous and interesting. The red-winged blackbirds nest in reeds and eat seeds and insects. There are wading birds which walk through the shallow waters on their long legs, reaching down to the bottom of the swamp with their long necks and beaks to catch insects and small mollusks. Ducks make their nests on the hummocks, and swim about on the water in comparative

Although the swamp looks lifeless, the many moundlike muskrat houses show that beneath the water and in the tangled vegetation many living things make their homes.

safety. Mallards feed in water shallow enough to reach bottom by tipping up, while other ducks feed further out by diving into the deeper water for food.

Muskrats build their houses in the shallow water, using straw, roots, stems, and mud to form a conical mound, inside of which they leave a chamber for living room. Their food consists chiefly of roots and stems of water plants, some of which they store for use in the winter. They also eat freshwater clams and an occasional fish. Muskrats are quite safe from most enemies, for they swim easily for hours.

Mice run about on the matted grasses of the swamp and build curious nests of grass and down.

The minks are the most deadly hunters of the swamp animals, for they capture muskrats, birds, mice, and any small animals they can find. Minks are powerful fighters, and can kill animals much larger than themselves. They belong to the weasel family.

There are many other inhabitants of the bogs and swamps —snails, water snakes, frogs, and fish. Each must protect itself from its enemies while obtaining food. The muskrat eats young ducks, and the wily coyote eats the muskrat for

his dinner. Every animal has its enemy, and every plant is possible food for some animal. It is in the swamps that the huge moose chooses to feed on tender grasses and water plants.

What are some other communities? There are many communities. Ponds offer an assortment of life different in many respects from that of bogs and swamps. Forests of the type found on dry ground differ from forests found along rivers and lakes. The desert community is entirely different from the moist-region community.

Communities do not always remain the same. A pond community after a period of dry years may become a swamp or even a dry-land community, with new plants and animals appearing as the climate changes. Then when wet weather returns, the pond community may gradually re-establish itself. A fire passing through a forest community changes it entirely, for the plants which grow up following the fire are not the same as those which lived in the forest before.

Exercise. *Complete the following sentences:* A community is a region of similar conditions of —1—, —2—, and —3—. It must contain a variety of plants and animals in fairly good —4—. These animals include those which eat —5— and others which eat —6—. There are —7— and larvae of insects in the soil. Man upsets the —8— of communities by removing some species and introducing others. Communities change as the —9— changes or when some unusual occurrence, such as a —10—, changes conditions of life.

Science activity. Prepare a report on one of the other types of communities mentioned briefly in this problem. Consider a farm wood lot or a city dump as a community if you cannot study any larger area.

A Review of the Unit

Animals are adapted for survival by possession of structures and types of behavior suited to the environment in which they

live. They solve their life problems in many different ways, but all have the same problems of reproduction, food-getting, metabolism, movement, and defense.

The structures of plants and animals vary around a few basic plans. Plants or animals which are similar in most respects are classified together. The basis of classification is structure.

Living things cannot exist alone, for they depend upon each other for food and air. Nor can they exist when there is too much competition for food, space, and other needs. The greatest good results when a community of living things is in balance—that is, when various kinds of plants and animals live in numbers sufficient that many members of each species can survive, and no species exists in numbers sufficient to destroy its own food supply.

An exercise in thinking

Match the principles and related ideas, according to the directions given in the review at the end of Unit I.

List of principles

A. Life is a series of chemical changes that take place in protoplasm.

B. Structure of an organism determines in what environment it must live.

C. Environment determines what types of living things eventually survive.

D. Every living thing is dependent in many ways upon other living things.

E. Osmosis is the exchange of liquids of differing densities through a porous membrane.

F. All living things are able to respond to stimuli in the environment.

G. All living things are able to use food to provide energy.

H. All living things are able to move to carry on their life functions.

I. Growth is an increase in size or in complexity or parts of an organism.

J. All living things start life from a one-celled stage.

List of related ideas

1. Algae absorb water containing minerals through their cell walls.

2. Metabolism includes the process of breaking down food to release energy in the cells.

3. Algae increase in number by cell division.

4. When a continent sinks beneath the sea, all life on it becomes extinct.

5. Animals give off carbon dioxide which is used by plants.

6. In order to get light, grapevines must be supported by their twining tendrils.

7. Plants give off carbon dioxide when they use the food they make.

8. Many reptiles which once required a warm climate are now extinct.

9. An adult insect has many parts not found on the larva.

10. There is a constant streaming motion in protoplasm.

11. Animals require nitrogen compounds to build protoplasm.

12. Water passes from leaf veins through the cell walls into the cells.

13. A plant which lives on decaying organic matter is a saprophyte.

14. Nest-building is instinctive with most birds.

15. Fertilization brings together the two cells which start new organisms.

16. Most insects have the power of flight.

17. Larger organisms grow by cell division.

18. Leaves of plants often turn to follow the sun.

19. Energy obtained from the sun is released by oxidation of food in the tissues.

20. The unit in which protoplasm carries on life functions is the cell.

21. Water enters root hairs from the soil.

22. A lichen consists of two plants living together.

23. A plant usually weighs thousands of times more than the seed from which it forms.

24. Photosynthesis is the process of manufacturing food by green plants.

25. Fish have an air bladder and fins to maintain their position in the water.

26. In an egg there is a single fertilized cell which is alive.

27. The turning of a vine stem around a support is a tropism.

28. One-celled plants increase in size after they are formed by cell division.

29. Materials found in living things are not the same compounds that are used for food.

30. Plants seek water by extending their roots down into the soil.

31. As a pond dries up, organisms which lived there disappear and new organisms appear.
32. Instincts of insects are highly developed.
33. A ground squirrel has claws adapted for digging burrows.
34. Root hairs contain a sirupy sap, denser than water.
35. Bacteria and molds do useful work in causing decay.
36. A change in the amount of vegetable matter in the soil causes a change in the type of plants growing there.
37. Coloring which helps an animal to hide is called protective coloring.
38. Food must be digested before it can be used.
39. Some young birds do not have feathers.
40. All animals finally depend upon green plants for food.

Some things to explain

1. Why do insects occupy such a prominent place among living things?
2. Why is it sometimes difficult to determine whether a certain organism is a plant or an animal?
3. How does all life depend on the work of chlorophyll?
4. Explain how some common plant or animal not mentioned in the text is adapted to its environment.
5. Explain how some plant or animal is dependent on other living things.
6. What advantages does the possession of a backbone give an animal over one that does not have a backbone?

Some good books to read

The Book of Birds, The Book of Wild Flowers, National Geographic Society
Buck, Frank and Ferrin, Fraser, *On Jungle Trails*
Compton's Pictured Encyclopedia
Comstock, Anna B., *Handbook of Nature Study*
Dougan, L. M., *Stories of Outdoor Science*
Durand, Herbert, *Field Book of Common Ferns*
Fabre, Joan H., *Insect Adventures*
Hoogstraal, H., *Insects and Their Stories*
Jones, J. E., *Some Familiar Wild Flowers*
Krieger, L. C., *The Mushroom Handbook*
Lydekker, B., *Wild Life of the World*
Mann, P. B. and Hastings, G. T., *Out of Doors*
Mosely, E. L., *Trees, Birds and Stars*
Nelson, E. W., *Wild Animals of North America*

Picture by Dr. W. J. Breckenridge

This ruffed grouse is "drumming" by beating his wings on a hollow log in order to attract a mate. Many kinds of male birds court mates.

Pope, C., *Snakes Alive and How They Live*
Trafton, Gilbert H., *Bird Friends*
Verrill, A. H. *Strange Birds and Their Stories*
Wood, Clarence, M., *Insect Ways*

Courtesy Yerkes Observatory

UNIT THREE

HOW CAN WE EXPLORE THE DISTANT STARS?

A clear sky dotted with twinkling stars. . . . A grassy hillside bordering a mirror-surfaced lake. . . . Remains of a campfire with glowing embers casting unexpected shadows. . . . The perfect setting, not soon forgotten, to watch the steady movement of the stars as they seem to make their way across the sky. It is fun to watch the stars in camp, on overnight hikes, or just for an evening. You need not go to any special place to find them, although you will see them better if you are away from city lights.

Stars are always with us. They are not always the same stars, but if you watch them throughout the years, familiar ones return from time to time, and you will soon associate certain stars with the changing seasons. If you move to a different town in another part of the country, you will find the same stars in nearly the same positions.

Appreciation of the beauty of the stars, like the enjoyment of anything in nature, comes from continued contacts with them. At first you notice only that there are many stars of varying degrees of brightness. Some are very bright, while others can barely be seen.

As you continue your observations, you discover that certain groups of stars form figures, such as the Big Dipper. Through the night, or on successive nights, you note that the figures turn as they seem to move across the sky, but the stars keep the same position with reference to each other. The seven stars of the Big Dipper always stay as a dipper—whether it is upside down, right side up, or hanging in a vertical position. Such groups are called constellations [kŏn′stĕ·lā′shŭnz].

Constellations were known to primitive peoples, who named them after animals, objects, or their gods. Because certain combinations were to be seen at the beginning of spring, or when some unpleasant event occurred, they felt that the stars had power over their lives. Do you know of any modern ideas that are based on this belief? Today, we know that the movements of the stars occur because of certain well-established forces, and that our earth is a part of the whole system. Let us look at the stars and learn about them.

Courtesy Yerkes Observatory

It is possible to take pictures of stars which are not bright enough for us to see. The dimmest star we can see is more than 100 times brighter than the dimmest star shown in this picture, which was taken through a powerful telescope.

1. What are the stars?

Ancient peoples knew much about the stars. They knew when to look for certain ones, and they made maps of the sky during different seasons. However, they did not know what the stars were. They thought that the sky was a great up-side-down bowl with the stars located on it. They did not know that stars are at different distances from the earth, and they had little idea of the tremendous space through which light from them has to travel.

The stars which we see send very little light to us. The light of most stars is so feeble that ordinarily we cannot see them with the unaided eye. Man has been able to see stars by using special instruments (telescopes) to gather more light or by using photographic film which is sensitive to light that the eye cannot see. By means of this faint light, modern astronomers have discovered many interesting things about the stars.

What can this faint light tell us? A certain light in a small room may be very bright, but if it were used in a large hall it would seem to be quite dim. Actually it is still giving the same light, but the light goes out from it in every direction to light more space. As we get farther and farther away, the space becomes larger so that less light reaches a unit area. A great distance away, the light appears as a tiny point, as very little reaches the eye.

Kaufman-Fabry photo

In this planetarium spots of light are thrown upon the domed ceiling to represent stars and planets. The projector in the center can be used to show how the stars look now or how they have looked in the past or how they will look in the future.

Since stars are so far away, the fact that we can see the light at all is evidence that its source must be very large. If our sun were to move away from us, it would get dimmer and dimmer till finally, when it was as far away as the stars are, it, too, would look like a faint star. And if the stars were to approach us till they were as near as the sun, they, too, would look like the sun; some would seem smaller and others much larger than our sun.

How big are the stars? The sun is really a star. In response to the question, "How big are the stars?" we may answer, "They are about the same size as the sun." However, the stars differ greatly in their size. Some stars are

smaller than the sun, while others are many times larger. The largest star which has so far been measured is Antares [ăn·târ′ēz]. Its diameter is about 400,000,000 miles, or nearly 500 times that of the sun.

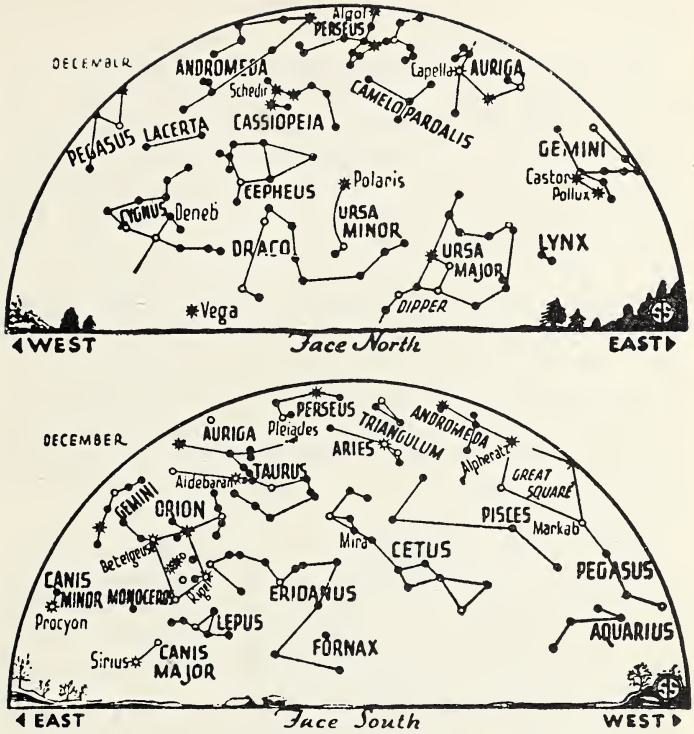
Why do the stars differ in color? A keen eye will notice that there is a difference in the color of the stars. Some look red or orange, some yellow, some white, and some blue. At different times in its history, the same star has different colors. Astronomers believe that the change in color is due to changes in temperature. We know that when iron is heated it first gets red. This color gradually fades as the temperature is raised, turning orange, then yellow, and finally white. If iron were able to obtain enough heat, the color would be an intense blue. It is the same with stars. A very hot star is blue. Rigel [rī′jĕl] in the heel of the constellation Orion [ō·rī′ŏn] is such a star. Most of the stars are yellow or white. Antares is a red star.

Far out in space, much too far for us to see with our unaided eyes, are huge clusters of stars. This round cluster is found in the constellation Hercules.

Courtesy Yerkes Observatory

Some astronomers believe that a star goes through a round of changes in temperature and color. If this is so, a star that is red now may become a blue star. Of course, this change takes millions and millions of years.

How far away are the stars? When we read that a distance is measured in millions of miles, we have no experience to tell us how far that is. If we wish to measure distances on the earth, we use the mile, since a mile has meaning to most people. The inch would not be a practical



Courtesy Science Service Map of the Stars and *Science News Letter*

This chart shows you the stars you can find in the December sky, with lines drawn to show how they may be grouped in constellations. The words in small print are the names of stars, those in large print the names of constellations.

unit. A number expressing the distance between New York and Chicago in inches would be so large that it would have no meaning.

Astronomers are faced with the same situation when they wish to measure distances. In terms of space, the mile is so short that a very large number would be required to tell the distance to the stars. For example, the distance to Sirius

[sĭr'ĭ·ŭs], the Dog Star, is 50,000,000,000,000 (fifty trillion!) miles.

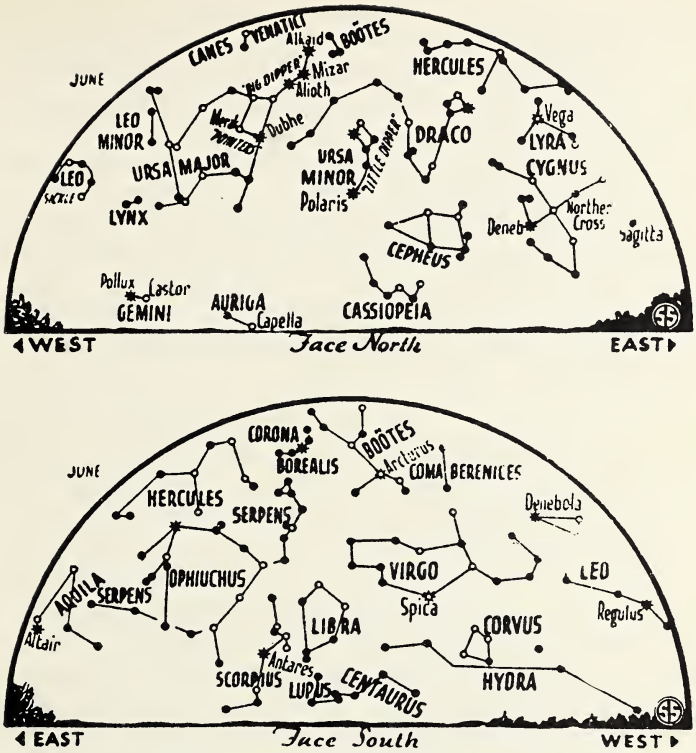
What unit can we use for measuring star distances? Since light travels a certain distance in a unit of time, some time unit can be used to represent distance. A light-year is the distance that light travels in one year. In order to understand just how far light travels in a year, we shall start with the fact that in *one second* light travels *186,000 miles.* This is more than seven times the distance around the earth. This unit is still too small to be practical for measuring in space. If we multiply 186,000 by 86,400, the number of seconds in a day, we get the number 16,000,000,000 (sixteen billion), which in miles is the distance which light travels in a day. This would compare to the use of the rod in our system. If we multiply this figure by 365, the number of days in a year, we get the large number of 6,000,000,000,000 (six trillion) miles as the distance light travels in one year. This figure is considered a practical unit.

How far away are the stars? Now let us apply the light-year to measuring distances to the stars. The nearest star is so far away that it takes light more than *four* light-years to reach the earth. In other words, it is about 25,000,000,000,000 (twenty-five trillion) miles distant. This star cannot be seen in the United States.

On some clear winter evening look at Sirius, the brightest star in the heavens. You will find it low in the southeastern sky. Remember that it is the closest star we can see in the United States. The light which now enters your eye left Sirius nearly nine years ago. Most of you had not started to school at that time.

Astronomers estimate that the North Star is probably about 450 light-years distant. That is, the light which enters your eye today started from the star about the time that Columbus discovered America.

Some stars are believed to be thousands of light-years away. Astronomers tell us that there are other stars that may be millions of light-years distant. These stars are out-



Courtesy Science Service Map of the Stars and *Science News Letter*

Compare this chart of the June constellations with that of December. Note that you cannot see Orion and that Polaris is the only star that has not changed its position.

side our galaxy [găl′ăk·sĭ, system of stars of which our sun is a part].

How many stars are there? Not nearly so many stars can be seen with the unaided eye as most people think. The largest number that can be seen during the whole year is about 5000. Since this is the total number all around the

earth, only one-half this number (about 2500) can be seen at any one time. However, for every star that you can see, there are millions that you cannot see. By means of the telescope and the camera, astronomers have discovered many millions of stars.

It is not possible to give the exact number of stars; but some astronomers estimate that the number in our galaxy may be as many as 100,000,000,000 (one hundred billion). But even this number, large as it is, represents only the number of stars in one galaxy. Astronomers have discovered many other galaxies, each of which may contain a billion or more stars. It is impossible to state exactly how many stars there are, but the number is very large.

——Things to think about——

Write the numbers from 1 to 10 on a piece of paper or in your notebook. Complete the following sentences to make true statements. Opposite each number write the word needed to complete the sentence.

Astronomers measure distance to the stars by the distance that —1— travels in one year. The nearest star is —2— light-years distant. Our sun is a —3— which is relatively near to us. The distance to the stars is much —4— than that to the sun. For every star that we can see with the unaided eye there are thousands that can be seen with the —5—. Astronomers believe that the —6— color of Rigel is due to its high temperature. Light travels 186,000 miles in one —7—. The distance to the nearest star is about 25 —8— miles. It takes light about —9— years to travel from the North Star to the earth. The largest number of stars that can be seen by the unaided eye at one time is about —10—.

2. How did the constellations get their names?

Many of the constellations were named centuries ago by the ancient peoples. Some of them were named after story characters, such as Cassiopeia, Hercules, and Orion. The

Lion, the Great Bear, and the Eagle were named after animals. Still others were named after objects, such as the Ark, the Northern Crown, and the Arrow. The ancients named about 48 of the brightest constellations. Since ancient times others have been named, till now the number of constellations is 90.

What are the names of some of the constellations? Most of the constellations have two names: a scientific name and a common name. Because the scientific names are hard to pronounce and hard to remember, most people prefer to use the common names instead of the scientific names. Following are a few examples of constellations, giving both the common and the scientific names.

COMMON NAME	SCIENTIFIC NAME
The Great Dog	Canis Major [kā′nĭs·mā′jẽr]
The Twins	Gemini [jĕm′ĭ·nī]
The Great Bear	Ursa Major [ûr′sȧ·mā′jẽr]
The Hunter	Orion [ō·rī′ŏn]
The Lady in the Chair	Cassiopeia (kăs·ĭ·ō·pē′yȧ]
The Lion	Leo [lē′ō]

Whatever the ancients may have thought about the shapes of the figures the stars seemed to make, few of the constellations look like the creatures or objects for which they were named. If you try to find shapes suggested by the names bear, lion, and so on, you will be hindered rather than helped in finding the constellations. The names are simply a convenient means of referring to certain constellations.

However, portions of some constellations have received special names. These groups of stars look very much like their names. For example, a part of the Great Bear is called the Big Dipper. These stars make the shape of a dipper with a bowl and a long, curving handle. Likewise, the stars in the Little Dipper, which is part of the Little Bear, have the shape of a dipper. A part of the constellation the Lion is called the Sickle. These stars look like a sickle with a handle and a curving blade. The Northern Cross in the Swan consists of two rows of stars looking somewhat like a cross.

The clusters of stars which make up a constellation do not make a complete outline of the figure. Indeed, it takes a good imagination to see the Hunter, Orion, in the stars.

How are the stars named? Some of the brighter stars, such as Polaris, the North Star, and Sirius, have received individual names. About 30 of the brightest stars have thus been named.

Astronomers formerly used another method of naming the stars. The stars in each constellation were named after the letters of the Greek alphabet. The brightest star in a constellation was named Alpha, the first letter in the Greek alphabet; the second brightest star was named Beta, the second letter in the alphabet, and so on. The Greek letter is written first and then the name of the constellation after it. For example, the name for the North Star is Alpha Ursae Minoris (Alpha of the Little Bear). This name means that the North Star is the brightest star in the constellation of Ursa Minor (the Little Bear). After the letters in the Greek alphabet were all used, then the Roman letters were generally used.

Since many stars have been discovered, astronomers make catalogues of stars in which the stars are simply numbered according to their position in the sky.

What are the stories of the constellations? The ancients had stories about the constellations which explain how their names were given to them. Stories were told about the Twelve Labors of Hercules [hûr′kŭ·lēz], about Orion, the Hunter, and about the Great Bear and the Little Bear. Here is one of the stories about the Great Bear and the Little Bear.

At one time there lived on the earth a very beautiful woman named Callistro and her little son Arcas. Jupiter, king of the gods, was attracted by her, but Juno, his wife,

was so jealous of Callistro's beauty that in a fit of rage she changed this beautiful woman into a bear. Callistro, now changed outwardly into a bear, was still a human being inwardly. She wandered unhappily through the woods, seeking to avoid both bears and people. Her son Arcas grew up and became a famous hunter. One day he came face to face with his mother. Not knowing, of course, that this bear was his mother, he raised his spear to hurl it at her. Out of pity for this mother and her son, Jupiter saved the mother's life by changing the son into a bear. Thus they both lived for a while as bears. Finally, Jupiter took them from the earth and placed them in the sky as two constellations: Callistro as the Great Bear, and Arcas, her cub, as the Little Bear.

The constellation the Great Bear is found in the northern sky. Can you find the Big Dipper which makes up part of the bear's body and his tail?

When Juno saw Callistro and Arcas shining in the heavens, she was angry at what Jupiter had done. So she went to the god of the oceans and demanded that he never allow these constellations to sink into the cooling waters of the oceans. Her demand was granted. So the Great Bear and the Little Bear circle around the North Star without ever setting.

——Things to think about——

Write the numbers from 1 to 10 on a piece of paper or in your notebook. Complete the following sentences to make true statements. Opposite each number write the word needed to complete the sentence.

The —1— named the Great Bear does not look like a bear. The astronomer's name for the —2— is Alpha Ursae Minoris. Ursa Major is the scientific name for the

constellation commonly called the —3—. The scientific name for the constellation commonly called the Twins is —4—. The Big Dipper is a part of the constellation called the —5—. The Little Dipper is a part of the constellation called the —6—. The group of stars known as the Northern Cross is in the constellation called the —7—. The common name for the constellation Leo is the —8—. The group of stars known as the Sickle is in the constellation —9—. —10— is the scientific name for the constellation commonly called the Hunter.

——Science activity for fun——

Look up some other stories of the constellations and report on one to the class.

3. How can we find some of the constellations?

The method of identifying the stars is different from that used in identifying such things as birds and trees. We can identify a robin from its size and color; we know a maple tree from the appearance of its leaves. In each instance we can identify certain trees, birds, or flowers by looking at only one object. With the stars, however, there is no such simple method of identification.

In order to identify the stars and constellations, we must know their position as related to that of other stars. The stars in a constellation always keep the same position with reference to one another. Therefore to identify a certain constellation we look for a cluster of stars which are arranged in a certain way. We can identify particular stars by their position in this constellation and in some cases by their brightness.

Can star maps help us name the stars? To identify the constellations, we first need some star maps showing the arrangement of the stars in the constellations. It is easiest to begin with a study of the polar constellations. The term "polar" is applied to those constellations which never set but

In order to locate the stars, we can use these constellations for guides. Because they are near the North Star, they are always visible.

which seem to circle around the North Star, always keeping above the horizon. They can be seen on any clear night. However, their position in the sky changes from month to month.

How can we find the polar constellations? Look at the map of the polar constellations. To use this map, face north and hold the map in front of you a little above the level of your eyes. Turn the map so that the present month is at the top. The map shows the positions of the constellations at nine o'clock. If the time is an hour earlier or later, turn the map slightly toward the month earlier or later.

The Big Dipper. In learning to find the constellations, begin by identifying the Big Dipper. It is easily found. The seven stars in this group make the shape of a dipper, with four stars in the bowl and three in the handle. All but one of the seven stars are of the same brightness. The second star from the end of the handle is a double star. The Big Dipper is commonly called a constellation, although it really is just a part of the Great Bear. Many constellations can be found from their position with reference to the Big Dipper.

The figure shows that in May the Big Dipper is nearly overhead but that in November it is low, near the northern horizon. In August it is at the left of the North Star, and in February it is at the right of the North Star.

The North Star. To find the North Star, start with the two stars, called the pointers, at the end of the bowl of the Big Dipper. Draw an imaginary line between these pointers and extend this line on the side of the open part of the bowl. Imagine this line extended about five times the distance between the two pointers. It ends near the North Star, which is also called Polaris. The pointers and the North Star were the guides of sailors for thousands of years.

The Little Dipper. The Little Dipper is part of the constellation called the Little Bear. It can easily be located from the North Star, because the North Star is the end star in the handle of the Little Dipper. The rest of the Little Dipper extends on the side toward the handle of the Big Dipper. As in the Big Dipper, there are seven stars in the Little Dipper: four in the bowl and three in the handle. The open parts of the two bowls face each other. The four stars of the bowl represent four degrees of brightness. It is a test of keen eyesight to be able to see the dimmest of these stars. The two outer stars in the bowl are called guardians of the pole.

What are the winter constellations? As the winter season advances, the stars are seen farther and farther towards the west if we check their position at the same hour each night. By looking every hour or two through the night we can see the different positions occupied by the constellations

Sirius, the Dog Star, is the brightest star in the sky. The constellation the Great Dog is following Orion, the Hunter, across the sky. These constellations are seen only in winter in the United States.

later during the year. Because of this movement, stars which we see in the fall will gradually disappear under the western horizon, and new stars will appear in the east. By January the sky directly overhead will contain nearly all new constellations.

Orion, the Hunter. Orion can easily be found by referring to the map. During the last of January Orion is found at its highest point in the sky at about nine o'clock. At this time it is about halfway between the zenith [zē'nĭth, the point in the sky directly overhead] and the southern horizon.

If we wish to find the form of the Hunter, as Orion is sometimes called, the two bright stars in the northern half may be called the shoulders. The two bright stars in the southern half are the heels. The three bright stars between the shoulders and the heels are the belt, and the stars below the belt mark the sword.

Courtesy Yerkes Observatory

This photograph of Auriga was taken with the telescope out of focus (see illustration on page 176). Can you find Auriga with the aid of the star maps?

Orion is the brightest constellation in the entire heavens. It shines in the southern sky during the late winter. It is the only constellation which contains two stars of the first brightness. These two stars are Betelgeuse [bē′tl·jo͞oz], in the shoulder, and Rigel, in the heel. Betelgeuse is a giant among the stars. Its diameter is more than 300 times that of the sun. Rigel is so far away that its light takes 500 years to reach us.

Orion is also of interest because it is a guide to the winter heavens. Other constellations can be identified by their position with reference to Orion.

Auriga, the Charioteer. Directly overhead in the northern United States, a star of the first degree of brightness marks the northern boundary of the constellation Auriga [ô·rī′gȧ]. The star can be located on a line a little more than half the distance from Rigel, in the heel of Orion, to the North Star.

This star, known to ancient people as the "Star of Stars," is called Capella [kȧ·pĕl′ȧ].

Sirius in the Great Dog. The constellation known as the Great Dog is famous because it contains Sirius, the Dog Star, which is the brightest star in the sky. To locate Sirius, draw an imaginary line through the three stars in Orion's belt and extend it toward the horizon, a distance equal to four or five times the length of the belt. Sirius rises later than Orion and is lower in the southern sky.

What is the Milky Way? The Milky Way extends as a belt entirely around the sky, looking like a thin, hazy cloud. When examined with the telescope, this cloud is shown to be made up of millions of stars. However, the Milky Way is not a constellation.

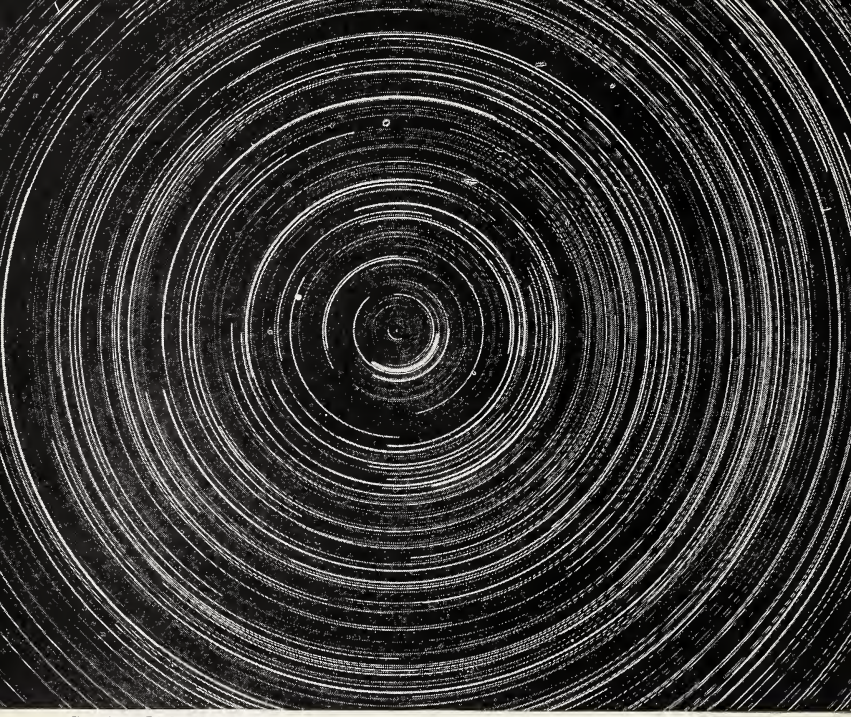
——Things to think about——

Write the numbers from 1 to 7 on a piece of paper or in your notebook. The first list contains the names of stars, the second list the names of constellations or groups of stars. Match the stars with their constellations. Write after the number of the star the letter for the name of the constellation or group of stars to which the star belongs.

Stars	*Constellations or Groups of Stars*
1. Betelgeuse	**A.** Big Dipper
2. Capella	**B.** Little Dipper
3. North Star	**C.** Great Dog
4. Rigel	**D.** Orion
5. Sirius	**E.** Auriga
6. Pointers	
7. Guardians of the pole	

——Science activities for fun——

1. Locate a few of the polar constellations. On any clear night take this book and a flashlight and go to some spot that gives a clear view of the sky and that is removed from the glare of street lights. Make a drawing in your notebook of



Courtesy Lick Observatory

When a camera is pointed at the North Star for several hours at night, the stars leave circular trails. The apparent motion of the stars results from the real motion of the earth, which rotates on its axis.

the stars in these three constellations, showing their relative positions.

2. Locate some of the winter constellations. Stand facing south. Look at the map on page 173. First find Orion. Then find the Great Dog and Sirius. Find Capella. Make drawings in your notebook of the constellations you find.

4. Do the stars move?

Most of the stars seem to rise in the east and set in the west. If you will go outdoors in the early hours of some clear night, you can observe the processions of the stars. In the first part of February, looking directly south, you may

see, about halfway between the horizon and the zenith, the constellation of Orion, the Hunter. Other stars can be seen to the east and to the west. Locate the position of the Hunter with reference to some object on the earth, such as a building or a clump of trees. Go out again an hour or two later and look for the Hunter. It has moved westward. Some stars which you saw earlier in the west have now disappeared from view below the western horizon. As you look toward the east, you will see rising there a very bright star, Sirius, which you could not see the first time you were out. As you watch the stars from hour to hour, they seem to move westward across the sky.

How can this motion of the stars be explained? The stars really do not move as they seem to do. What really happens is that the earth turns on its axis once every 24 hours. Since the earth rotates, or turns, from west to east, the stars and the sun seem to move across the sky in just the opposite direction, that is, from east to west. That is why they seem to rise in the east and set in the west.

You may have had the following experience, which will help you to understand how the motion of one body will make it seem as though some other body were moving. Perhaps you have gone to the railroad station to take a ride on a train. As you sat in the train waiting for it to start, you noticed another train on the track beside you. Then it seemed to you that the other train was starting to move. But finally you realized that it was standing still, and that it was *your* train that was moving. So it is with the stars. It is the earth which is moving, not the stars.

If the earth rotates every 24 hours, how fast do objects on its surface move? Since the distance around the earth is about 25,000 miles, objects on the equator move at the rate of about 1000 miles an hour. At points between the equator and the poles, the speed is less. In the United States, at latitude 40 degrees, objects on the earth's surface move at the rate of about 750 miles an hour.

Why do some stars never rise and set? Although we have

If you look at the Big Dipper at nine o'clock in different months, you will find that its position changes as shown in the diagram.

been talking about the rising and setting of the stars, there are some stars which never rise or set. They never sink below the horizon. Those stars near the North Star can be seen any clear night. Early in the evening in October, the big Dipper can be seen low down near the northern horizon. A few hours later it has moved farther over towards the right and is rising higher above the horizon. It moves around the North Star in a direction opposite from that in which the hands of a watch move, always keeping above the horizon.

All these stars near the North Star move around and around like a merry-go-round in the sky. This apparent change in the position of the stars is also caused by the rotation of the earth. Because the axis of the earth points to the North Star, the stars seem to rotate around this star. If a camera is pointed toward the North Star and the film remains exposed for a few hours, a star trail is obtained.

The North Star apparently keeps the same position during all hours of the night, every month of the year. You always know just where to find this star any night you wish to look for it.

As one travels south, the North Star seems to sink lower and lower in the sky till, seen from the equator, it lies on the northern horizon. At the equator all the stars rise and set. As one travels north, the North Star seems to rise higher and higher in the sky, till at the North Pole it is directly overhead. Here none of the stars rise and set. They circle around and around, always keeping above the horizon.

Why do we see different stars in summer than in winter? In addition to the daily motion of stars across the sky, the

stars have an apparent yearly motion. We have already observed that different stars are seen in different seasons. During the winter we see such constellations as the Hunter and the Great Dog. During the summer these constellations cannot be seen. Instead we see such constellations as the Eagle and the Lyre.

As we have learned, the daily rising and setting of the stars is caused by the daily rotation of the earth. The change in constellations from season to season is caused by another motion of the earth, namely, its yearly revolution around the sun. As the earth makes its annual journey around the sun, different constellations can be seen at night.

Do stars have a real motion? The motions of the stars we have so far been discussing are only apparent; they are caused by the motions of the earth. However, stars do have a real motion of their own, and they are moving very fast. The average rate of speed of the stars is about 18 miles a second, or nearly 65,000 miles per hour. Some stars travel 10 times as fast. So you see it is not correct to speak of the stars as "fixed."

The stars are so far away that the distance a star travels in a year is only a tiny fraction of the distance from the earth to the star. Therefore we cannot see any difference in the position of the stars. But in time there will be a great difference. Many thousands of years from now the constellations will have different shapes.

Some stars are moving away from us, and others are moving toward us. The bright star Vega [vē′gȧ], in the constellation the Lyre, is moving toward us at the rate of eight miles a second.

——Things to think about——

Write the numbers from 1 to 10 on a piece of paper or in your notebook. Complete the following sentences to make true statements. Opposite each number write the word needed to complete the sentence.

The Big Dipper (*top*) is gradually losing its shape. The drawing below shows how it will look 100,000 years from now. The stars are moving in different directions at different speeds.

The apparent motion of the stars across the sky from east to west is caused by the daily —1— of the earth. There are some constellations near the —2— which are above the horizon all the time. As seen from the —3—, the North Star is located above the northern horizon. As seen from the —4—, the North Star is located overhead. Different constellations are seen in the summer than in the winter because the earth —5— around the sun. The average speed of the stars is about 18 miles a —6—. The —7— star always seems to keep the same position. At the equator —8— of the stars rise and set, while at the North Pole —9— of the stars rise and set. The point in the sky that is directly overhead is called the—10—.

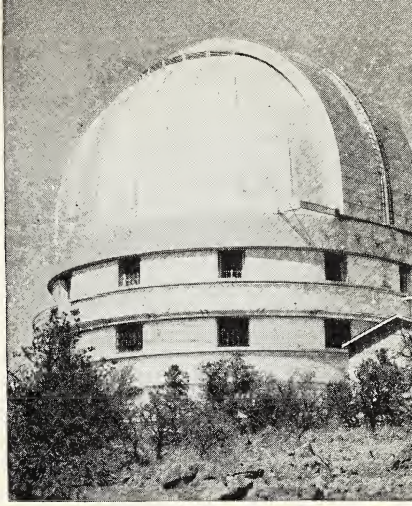
——Science activity for fun——

Select a constellation in the eastern sky as soon as it is visible in the evening. Measure the height of a principal star by using a stick held vertically at arm's length. Sight over your hand at the horizon to make sure that your arm is held at the same level. Slide the stick up in your hand until the star is just visible over the upper end. Make a mark on the stick above your hand. Repeat this each hour. Make a drawing in your notebook to show how the constellation has moved. Use the difference in position as measured with the stick to locate the star exactly on your drawing.

If you measure the angle between the line from your eye to the horizon and the line to the star each time you make a sight (once an hour) and subtract the preceding angle, you can determine the number of degrees the earth has turned.

Divide the difference into 360 degrees and you should get 24, the number of hours in a day.

5. What are the tools of the astronomer?

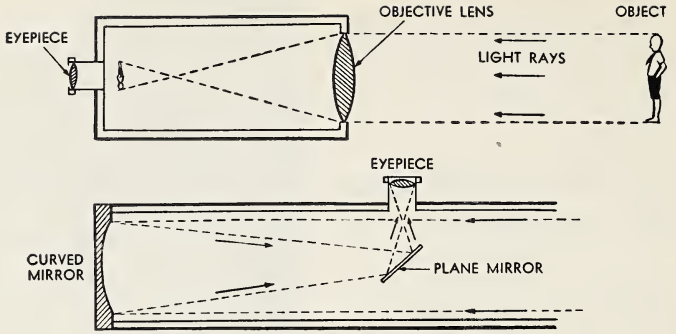


Pinkerton photo

McDonald Observatory in Texas contains one of the largest telescopes in the world.

When we hear of the ideas held by ancient peoples and learn the present beliefs about the stars, we may be inclined to wonder whether these newer facts are any more reliable. Were it not for the fact that modern students of the stars use certain tools not known to the ancients, we would be justified in wondering. Today man is no longer dependent upon his eyes alone. Because of the work of scientists, the astronomer has many fine tools to aid him in his study. They are as important to him as the saws, chisels, hammers, and workshop are to the carpenter. The workshop of an astronomer is called an observatory. His chief tools are the telescope, the clock, the camera, and the spectroscope [spĕk'trō·skōp].

Where are observatories built? The observatory must be in a spot where it will be easy for the astronomer to carry on his work. It must be away from the bright lights of the city. It must be in the open where there is nothing to interfere with the view. It must be where the weather conditions are favorable. Since the astronomer cannot use his tools in stormy or cloudy weather, he selects a place where the nights are usually clear. The roof of the observatory must have a large opening to permit the use of the telescope. The opening cannot be covered with glass, since glass would reduce



The mirror and the lens each make an image which is magnified by the lenses of the eyepiece. The biggest telescopes employ mirrors.

the amount of light. Therefore the room cannot be heated. So the observatory is also located where the weather is not too cold.

How is a telescope used? The most interesting of the astronomer's tools is the telescope. Modern astronomy may be said to have had its beginning with the invention of the telescope. It was invented by Johannes Lippershey, a Dutch spectacle-maker, more than 300 years ago. Galileo heard of it and built one from his own plans. He used it to study the heavenly bodies. Although this instrument was very crude, he discovered many interesting things, such as spots on the sun. He also found the moons of Jupiter, another planet which, like the earth, revolves around the sun.

How does a telescope work? The telescope shows many stars which cannot be seen without it. A telescope which has a lens only four inches across can be used to see more than a million stars.

The telescope is used also to make objects look larger. This use is valuable for the study of the nearer bodies, such as the moon and the planets. Even a small field glass shows many interesting features on the moon.

There are two kinds of telescopes, one that uses curved mirrors, and another that uses lenses. A lens is a piece of

glass with curved surfaces. Examples of lenses are the glasses used in spectacles.

What are some famous telescopes? The largest lens telescope in the world is located in the Yerkes Observatory, situated on the shores of Lake Geneva in Wisconsin. The lens of this huge telescope is 40 inches (3⅓ feet) in diameter, and the dome enclosing the instrument is 90 feet across.

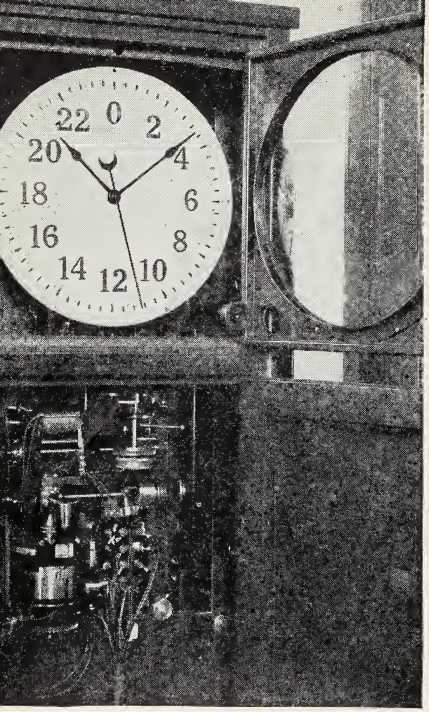
The largest mirror telescope in the world was put into service in 1942. Its mirror is 200 inches (16⅔ feet) in diameter. The mirror alone weighs 20 tons, and the whole telescope weighs about 500 tons, or 1,000,000 pounds. The telescope is so powerful it makes the moon, which is 240,000 miles away, seem to be only 24 miles away. Several years were spent building the telescope. It also took several years to make the machinery to carry it to the observatory.

The observatory is on the top of Mount Palomar, California, 90 miles from Los Angeles. This is one of the best locations for an observatory. The mountaintop is more than a mile high. The skies are clear more than 300 nights in the year. The weather is pleasant all year, neither very cold nor very hot.

How do we get the correct time? In nearly everything we do, it is important that we have the correct time. Astronomers have developed accurate timekeeping devices which they check regularly by watching the master clock, the movement of the stars. Because the earth rotates at a constant speed, the movement of the stars can be used as a clock.

To tell time by the stars, astronomers use a special type of telescope which can be pointed north or south or overhead. In order to see a star, the astronomer must wait until the earth has turned enough that the star crosses the field of view. As the light from the star crosses the center line in the telescope, a record is made.

The next time the star crosses the line in the telescope, it will be exactly 24 hours later. Clocks can be corrected and set in this way. Watchmakers and clockmakers have built



Courtesy U. S. Naval Observatory

This is an automatic time signal apparatus which broadcasts time by radio automatically every hour from 55 minutes to the hour.

very accurate clocks which are kept in the observatory. Correct time is sent out by means of telegraph and radio from these star-checked clocks.

How is the camera used in star study? When used in connection with the telescope, the camera is an important aid in finding stars. The camera will disclose stars that even the most powerful telescope used alone cannot discover. A single exposure of a film may show in one small section of the sky as many as half a million stars.

The telescope is pointed to a certain region in the sky and the film exposed for several hours. An electric motor is attached to the frame carrying the telescope to keep the telescope pointed at the same stars. This motor turns at a constant speed, which is determined by a master clock at the power plant.

For what is the spectroscope used? By means of another instrument called the spectroscope, astronomers can tell what stars are made of and how far away they are. They can even tell how fast stars are moving and in what direction.

Demonstration. How Does a Lens Form an Image?

What to use: A reading glass, a piece of paper.
What to do: Stand on the side of a room farthest

from a window. Hold a reading glass so that it faces a window. Hold a piece of paper on the side of the glass away from the window. Move the glass back and forth.

What was observed: What appears on the paper? In what two ways does the image differ from the window?

What was learned: Select the correct conclusion.

(*a*) The image formed by the lens was right side up.

(*b*) The image formed by the lens was larger than the object.

(*c*) The image formed by the lens was upside down and smaller than the object.

——Things to think about——

Write the numbers from 1 to 10 on a piece of paper or in your notebook. Complete the following sentences to make true statements. Opposite each number write the word needed to complete the sentence.

The astronomer's workshop is called an —1—. Some telescopes use —2— and some use —3—. The first telescope was invented about —4— years ago. The —5— is an instrument which helps astronomers tell of what stars are made. The largest telescope in the world has a —6— which is 200 inches in diameter. By means of a telescope Galileo discovered the moons of —7—. The largest lens telescope in the world has a lens whose diameter is —8— inches. The —9— is used to tell time by the stars. —10— was the first man to use the telescope to study the heavenly bodies.

——Science activity for fun——

A simple telescope can be made by the use of two reading glasses of different size. Find out, as in the demonstration on page 194, how far away from each glass a paper needs to be held to form an image. Do this with both glasses. Use the

one forming the image at the greater distance as the outer or objective lens. Locate the second lens, or eyepiece, where you can see the image formed by the first. If you will fasten these glasses in position by tying them to a stick and wrap a piece of black paper around them, you will have a fairly good telescope. As you look at rather near or far objects, you may need to move the eyepiece closer or farther away from the objective lens.

A Review of the Unit

Our sun is really a star. The stars do not look like the sun because they are so far away. The distance to a star is best described in light-years. We can see only the brightest stars with the unaided eye, so only about 2500 stars can be seen at one time. Stars may be identified by finding the constellations in which they are located. Polar constellations are those which never sink below the horizon. The stars do not have a visible motion, but because of the motions of the earth, they appear to move. New stars are seen during different seasons because of the positions of the earth as it moves around the sun. Real motion of the stars does occur, but because they are so far away we are unable to detect it. Modern apparatus has made information about the stars more reliable.

An exercise in thinking

Below are two groups of sentences. The first group contains principles, which are large general ideas. Each sentence in the second group contains an idea related in some way to one of the principles in the first group. Write the numbers from 1 to 20 on a piece of paper or in your notebook. Find the principle which best explains the idea in the second list. Then after the number on your paper write the letter before the related principle.

Example: A line following the curve of the stars in the handle of the Big Dipper points to Arcturus. The correct letter for the example sentence is **C.**

List of principles

A. Space is vast.

B. The earth's axis points to the North Star.

C. Orion and the Big Dipper are guides for locating other constellations.

D. A telescope gathers more light than the eye.

E. Stars seem to move because of the rotation of the earth.

F. Hot objects give off light.

G. Movement of the stars is not noticed because they are so far away.

List of related ideas

1. There are billions of stars.
2. Stars shine by their own light.
3. The first stars to appear in the early evening are the brightest.
4. Stars look small because of their great distance.
5. The stars seem to revolve around the North Star.
6. The three stars in Orion's belt point toward Sirius.
7. By means of the telescope many stars have been found which cannot be seen by the unaided eye.
8. Distances to stars are measured in light-years.
9. On the average, stars move at the rate of 18 miles a second.
10. The stars seem to rise and set.
11. The pointers in the Big Dipper point toward the North Star.
12. The telescope makes such objects as the moon and the planets look larger.
13. Vega is moving toward the earth at the rate of eight miles a second.
14. Stars are very hot.
15. The nearest star is four light-years distant.

16. In the United States the Big Dipper is visible any clear night.

17. The sun rises in the east and sets in the west.

18. The stars are not really "fixed."

19. The North Star is about 450 light-years distant.

20. When a camera is pointed to the North Star, a star trail is made on the film.

An exercise to test yourself

Write the numbers from 1 to 10 on a piece of paper or in your notebook. Opposite each number write the letter before the word or group of words which best completes the sentence.

1. The Big Dipper is a (*a*) comet (*b*) solar system (*c*) meteor (*d*) group of stars.

2. The constellation which never sets for one living in the United States is (*a*) Orion (*b*) the Great Bear (*c*) the Great Dog (*d*) the Lyre.

3. The nearest star is (*a*) one light-year away (*b*) two light-years away (*c*) four light-years away (*d*) 10 light-years away (*e*) 100 light-years away.

4. The largest star is (*a*) smaller than the sun (*b*) larger than the sun (*c*) the same size as the sun.

5. The number of stars that can be seen through the whole year by the unaided eye is (*a*) 100 (*b*) 1000 (*c*) 5000 (*d*) 100,000 (*e*) 1,000,000.

6. The instrument which shows what the stars are made of is the (*a*) spectroscope (*b*) telescope (*c*) camera.

7. The apparent rising and setting of the stars is caused by the (*a*) revolution of the earth (*b*) rotation of the earth (*c*) actual motion of the stars.

8. The North Star belongs to the constellation called (*a*) Orion (*b*) the Great Bear (*c*) the Little Bear (*d*) the Great Dog.

9. The only constellation that has two stars of the first brightness is (*a*) the Great Bear (*b*) the Little Bear (*c*) the Great Dog (*d*) Orion.

10. The brightest star is (*a*) the North Star (*b*) Capella (*c*) Sirius (*d*) Vega.

Some things to explain

1. Why were some of the constellations named after animals and mythical characters?
2. Why is the Big Dipper a good group of stars to begin with when studying stars?
3. Why do some stars never rise or set?
4. Why do astronomers use the light-year instead of the mile in expressing distances to the stars?
5. Why does the North Star always keep the same position?
6. Why do we not see the stars during the daytime?

Some good books to read

Fontany, E., *Other Worlds than This*

Lewis, I. E., *Astronomy for Young Folks*

Olcott, W. T., *The Book of the Stars for Young People*

Swezey, G. D. and Gable, J. H., *Boy's Book of Astronomy*

White, W. B., *Seeing Stars.* Often may be obtained at ten-cent stores

Wylie, C. C., *Our Starland*

Cypress Hills seen from the air. M. H. Kesterton Photo.

UNIT FOUR-A

WHAT STORIES CAN WE READ FROM ROCKS

As we travel over the prairie, through the forest, or along the stream, we observe many features of the earth's surface. If we extend this trip to a tour across Canada from east to west, we will see many kinds of scenery. In the Middle West are rolling hills, broad valleys marked with squares of growing farm crops, and beautiful lakes reflecting their shores and the sky.

Farther on we see level plains crossed by gently curving rivers with steep valley walls. Still farther are rugged, tree-covered mountains with massive rocks reaching high in the air beside swift flowing streams. Beyond these are higher mountains, whose white-capped peaks are only occasionally visible among the clouds hovering about them. Finally, the great Pacific Ocean blocks our way, as it surges and breaks against rocky shores, or rolls in long, foaming waves over sandy beaches.

While observing these things, it is difficult for us to believe that the whole earth has been changed over and over again, and is still being changed.

Fortunately, we are able to discover these changes by closer observation of the rocks and soil and the effects of the forces at work upon them. As we study the rocks and learn how they were formed, we slowly piece together the story of the earth. We find out what materials exist in the earth's surface, and how they may be of use to us. We see the changes that these rocks undergo. By careful study of the story told by the rocks, we determine not only what the forces of change are but also how long they will continue to operate.

We need not travel to distant places to learn these things. Wherever we may be, rain falls and washes over the surface of the ground. Winds blow and large quantities of dust are moved. The seasons come and go, and the sun provides heat for plants of many kinds, whose roots are deeply buried in the soil. While the heat of the earth does not show its effects at the surface everywhere, evidence of its presence may be found to aid us in our study. Let us turn to the earth, then, to see if we can read some of its story.

Courtesy Pan American Airways

Volcanoes often build huge, cone-shaped peaks of heat-formed rocks. This peak is Cotopaxi in Ecuador. Why is there snow on the upper part?

1. What surface changes are caused by volcanic action?

Long years ago, millions of years before people lived on the earth, the action of volcanoes produced many changes in the earth's surface. Today there are few volcanoes upon the earth, which is fortunate, for they are the most terrifying and destructive of all forces of nature. Yet we live now upon rocks which long ago were brought to their present places by the action of volcanoes.

What is a volcano? A volcano is a hole in the earth from which molten rock (lava), steam, and ashes are thrown. In a violent volcano an explosion starts the rock flow, and throws smoke, gases, ashes, cinders, and molten rock high

into the air. From volcanoes that are quiet the lava flows over the countryside, coming from mountaintops or huge cracks in the earth. Sometimes lava flows underground, and there is no activity above the ground at all.

The mountains through which volcanoes are likely to burst are formed by volcanic activity. Rock is melted under the ground, and breaks through a weak place or crack in the rocks to the surface of the earth as lava. The lava flows out and cools, forming rock. More lava flows, cools, and builds the rock higher. Usually the lava in the center of the volcano remains melted, and only the lava that flows out at the top cools and hardens. Thus we see that the volcano is built from the center outward. The molten rock flows upward through the central opening, which is called a chimney. During its many years of activity the volcano may change what was once a flat piece of ground into a huge cone-shaped mountain. Mount Rainier and Mount Shasta are examples of the magnificent peaks formed in this way.

The funnel-shaped opening at the top of the volcano is called a crater. In many volcanoes molten rock remains in the crater long after the mountain itself is cooled.

What makes a volcano erupt? We know that the temperature in the interior of the earth is very high, since volcanic eruptions bring molten rock to the surface. The exact cause of the earth's heat today is unknown, but several explanations have been suggested. One is that the pressure of the rock on the surface causes it. Another idea is that the movement of rock deep in the earth develops enough heat to melt the rock. Still another is that certain elements are breaking up with a loss of heat great enough to melt the rock containing them in spite of the pressure. Whatever the cause of the heat, sufficient pressure is developed to force hot rock through cracks.

At first this pressure is released explosively, and lava, ashes, and steam and other gases are thrown high in the air. After the path is cleared, the lava may be forced to the surface through the central opening, where it overflows quietly.

Crater Lake, in Oregon, is formed in the crater of an old volcano. The steep sides of the crater form the lake shore.

How does a violent volcano act? There are no violent volcanoes in the United States. But about 30 years ago in the mountains of Alaska there took place one of the greatest volcanic explosions in modern times. When this explosion took place, the whole top of a large mountain was blown into the air. A hole three miles across was opened in the top of the mountain, and the mountain was made flat on top where there once had been a lofty peak. Pieces of rock were blown over the countryside. Hot lava poured down the side of the mountain. The noise was so great that it was heard in Juneau, Alaska, which is 750 miles away, a distance as great as from Calgary to Winnipeg. Dust was blown so high in the air that it fell on the ground several hundred miles away. The odor of the smoke was smelled 1500 miles away.

What evidence can we find of volcanic action? During the formation of the earth, volcanoes were found widely distributed over the land. Proof of their existence may be found in the occurrence of widespread and very thick deposits of volcanic materials. The entire Columbia River Plateau, covering parts of the states of Idaho, Washington,

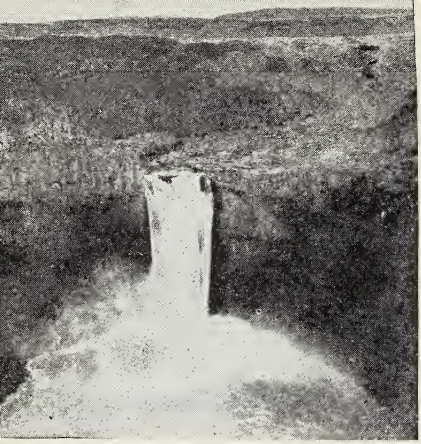
In the middle of the lake is a cone formed after the first crater was left by the caving in of the old crater bottom.

and Oregon, was built up of successive layers of molten rock until its total thickness is more than 5000 feet. The Hudson River has cut its channel in a massive deposit of rock which was once melted by volcanic action.

From this evidence we must assume that the earth in the beginning was very rough, made up of high mountains and deep valleys. These mountains must have been composed chiefly of granites. During the period of adjustment following this volcanic activity, violent shifting of the earth's crust occurred. These movements were accompanied by earthquakes far more vigorous than any of recent times.

What causes earthquakes? Earthquakes occur in all parts of the world, but they are more common in regions where there are volcanoes. Earthquakes are caused by movement of the crust of the earth. In an earthquake everything seems to be moving as if on a huge wave.

It is thought that the crust moves because some parts of the earth are made of heavy rock, and some of lighter rock. The heavy rock settles, causing the lighter rock to move. Also, surface cooling and contraction cause shifting of large



Courtesy Spokane Chamber of Commerce

This small river has cut its valley through seven layers of volcanic rock, each layer representing a flow of lava. The falls is 198 feet high. This lava flow, in eastern Washington, is part of one of the largest lava flows on the earth.

areas of rock. When the shift occurs, it may be so sudden that the shock may be very great.

The earthquake which caused the famous San Francisco fire in 1905 was the result of a shift along an old break which has been traced for 600 miles. The movement was entirely sidewise in this case, but a few years later an earthquake occurred in southern Italy which was caused by an up-and-down movement. Sometimes cracks are opened several feet across.

It is difficult to think that the rocks and soil on which we live are able to move. Yet they are. Whole cities have been destroyed by the shocks, and many millions of people killed by earthquakes. Most earthquakes occur in regions where mountains are being formed, but no portion of the earth is free of them. There are several observation centres in Canada where earthquakes are recorded by instruments called seismographs [sīz′mō·grȧfs]. A modified form of these instruments is used by oil exploration crews in Alberta.

——Things to think about——

Write the numbers from 1 to 10 on a piece of paper or in your notebook. Complete the following sentences to make true statements. Opposite each number write the word needed to complete the sentence.

There are two types of volcanoes, —1— and —2—. The —3— volcano builds up a volcanic cone. The opening from which lava flows is called a —4—. Proof of the existence of

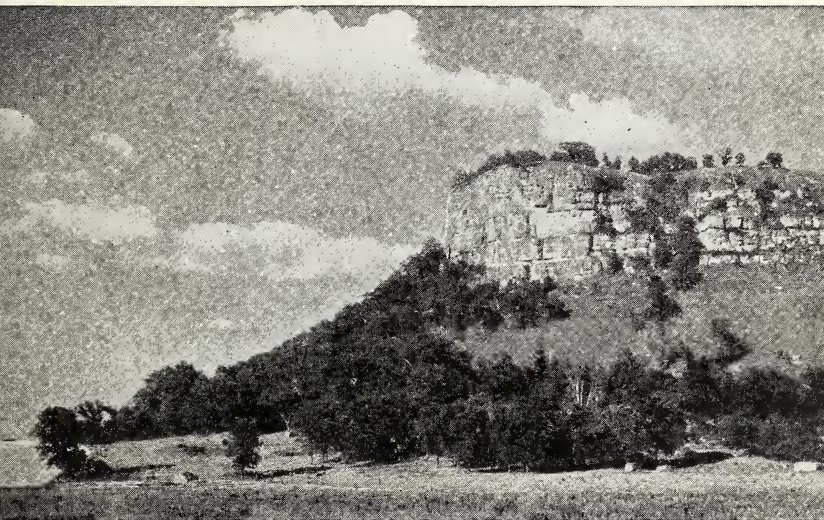
periods of intense volcanic action in the past is found in the occurrence of very —5— deposits of volcanic materials. Most active volcanoes are found in regions where —6— are being formed. —7— are caused by movements in the earth's crust. Movements of the earth's crust may be —8— or —9—. Seismographs are used to record the earth's —10—.

2. What stories can we learn from stones?

Many millions of years ago, after the great masses of melted rock had poured out on the surface of the earth, the rocks cooled and heavy rains came. As the water washed down the slopes, it carried with it particles which had been loosened from the surface of the rocks. After millions of years, the particles built up layers of rock thousands of feet thick. After more millions of years, the layers of rock and the original melted but cooled rock were worn away by water and wind, were moved by earthquakes and remelted by volcanoes, were tilted, folded, and stood on edge, until the rocks were greatly changed.

This limestone rock bluff was formed ages ago under water from the shells of animals. Today the rock is gradually changing to soil, as running water, heat, and weather break the rock. The slope on which the trees grow was once part of the rock.

Kenneth M. Wright photo



Each rock contains within itself a story of the changes through which it has passed. We can understand some of these stories rather easily, while others are not so easy to learn.

What can we learn from observing a pebble? From the shape and appearance of a pebble, we can learn something of its story. A smooth, round pebble has been worn smooth by the action of running water or of waves. A piece of broken rock is rough, and has sharp corners. As water rolls it along, it bumps into other bits of rock till the corners are worn off, and the pebble becomes smooth and rounded. Wearing a pebble smooth requires many years.

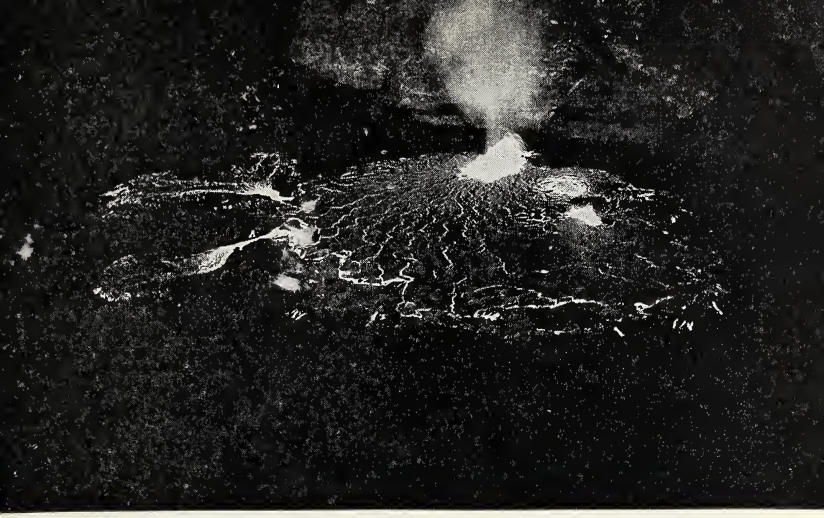
In parts of the country which have been covered by glaciers [glā'shẽrz, large, moving ice masses] you may occasionally find a pebble ground flat on one side, showing the scratches made when it was dragged by the moving ice against larger, hard rock. The larger rocks over which the glacier moved also show scratches made by the grinding of the pebbles.

How can you make a rock collection? As you explore the out-of-doors, it is worth while to collect pebbles and bits of rock to take home for future study. You will find that they are interesting, and that many of them are attractive to look at. They will repay your study by helping you to learn more about the earth on which you live.

You may find stones in many places. Sand and gravel pits and quarries provide many kinds of rock. A cut through a hill for a new road will expose still more. If you live in a part of the country once covered by glaciers, the soil may contain pebbles of many kinds. Another good place to look for stones is along streams and lake shores, for water washes away the loose soil, and leaves the heavier pebbles behind.

It is helpful to carry a small, strong hammer to break open pebbles to find clean, unstained surfaces of rock. A hammer is useful for breaking small pieces from larger rocks.

It is convenient to keep your rock collection in cigar boxes, or in strong, cardboard egg containers.



Courtesy U. S. Department of the Interior.

All heat-formed rocks have passed through a melted stage. In this Hawaiian volcano fountains of melted rock 25 to 75 feet in height are building rock cones.

How can you sort your rocks? Rocks may be sorted into three groups. In the first group you will place those rocks which were once melted by volcanic action. This group of rocks is made up of materials melted together which, as they cooled, separated out to form closely joined crystals [krĭs′tălz, bodies formed by cooling, having certain definite shapes]. These heat-formed rocks are quite hard. One of the most common is granite, which contains three kinds of crystals. One kind, quartz [kwôrts], breaks with the surface like tiny oyster shells; another kind, feldspar [fĕld′spär], breaks with flat faces; and the third, mica, breaks into very thin sheets. Most other heat-formed rocks are similarly made up of closely joined crystals, although some are composed of crystals too small to see.

A second group of rocks is composed of fairly loose grains, and often shows layers of material of different sizes. These rocks have been deposited, either under water or by wind, and are usually loosely joined together. You can scrape particles of sand from most kinds of sandstone. Limestone was

W. H. Finch photo

Water-worn rocks are smooth. Holes were worn in this rock by pebbles and gravel whirled around by the running water of a river. Some potholes, as these are called, are as large as an ordinary room.

formed from the shells of sea animals which fell to the bottom of the ocean, and you can often find complete shells in limestone. Other kinds of limestone are made of microscopic shells. You can recognize limestone by a simple test. If you put a drop of hydrochloric acid on a rock and bubbles form, the rock is probably limestone. Shale, a soft wind- or water-deposited rock formed from clay, looks like a poorly baked brick.

A third group of rocks has been changed in form in some way, usually by heat or water or pressure. They are often streaked in appearance (do not confuse a streak with a layer), but are sometimes clear and glasslike. When limestone rock is changed by heat and pressure, it becomes marble. Shale changes to slate. Granite changes to a streaked rock called gneiss [nīs]. Sandstone changes to a hard, glassy-looking rock called quartzite.

The best way to name your rocks is to use a collection already named by an expert, and to compare your rocks with those named in the collection. You cannot expect to find every one of your rocks in a small collection, for there are hundreds of kinds of rocks and minerals. You should, however, be able to classify them into three groups: heat-formed, water-formed, and changed-form rocks.

Where are different types of rock found? The rocks which you collect are but small particles broken from the huge rocks which make up the surface of the earth. The layers of surface rock are in places thousands of feet thick, and in that thickness of rock may be found rocks of many types. The top layers of the earth's surface usually consist of water-deposited rocks, while below these are the rocks which have changed in form. Deep beneath are the heat-formed rocks,

which may in places exist much as they did at the beginning of the earth. In the deep valley of the Grand Canyon it is possible to see the edges of many layers of rock in the mile-high exposed cliffs which make up the valley walls.

Of course rocks are not always found in this order. Sometimes where there is recent volcanic activity, the heat-formed rocks lie on top of water-formed rocks, covering them completely. In other places, the action of ice or water may have worn away the upper rock layers, exposing types of rock usually found deep in the earth. By knowing the story of the rocks, we can often know how rocks were formed, and how they came to be in places where they now are.

Exercise. How Can We Identify Rocks?

What to use: Labeled samples of granites, sandstone, shale, slate, limestone, marble, gneiss, quartzite, etc. Pupils' collections. Coin, magnifying glass, knife, hydrochloric acid.

What to do: Examine each sample for appearance and size of crystals or type of grain. Test the hardness of all rocks by scratching with a knife blade, a copper coin, and your fingernail.

Test several, including limestone and marble, with acid.

Complete your work by labeling all your samples which are the same as those found in the school collection.

What was observed: Classify each rock which you observed. Tell why you decided it belonged with the particular group.

What was learned: Select the correct conclusion.

(*a*) Rocks can be identified by their color.

(*b*) Certain combinations of properties are needed to identify most rocks.

(*c*) All rocks are of uniform hardness throughout the sample.

——Things to think about——

Write the numbers from 1 to 10 on a piece of paper or in your notebook. Complete the following sentences to make true statements. Opposite each number write the word needed to complete the sentence.

Pebbles have been worn smooth and rounded by the action of —1—. Pebbles with flat, scratched faces were pushed along by —2—. —3— is usually composed of the three minerals: quartz, mica, and feldspar. —4— is a rock formed by heat. Rocks composed of fine crystals were formed by —5—. Particles may be loosened from —6— with your fingers. When limestone is heated under great pressure, —7— is formed. The outer layer of the earth is made of —8—. Rocks consist chiefly of mixtures of —9—. Many types of rocks may be found in regions formerly covered by —10—.

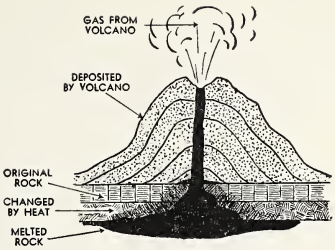
——Science activity for fun——

Make a collection of pebbles. Label as many as you can, indicating where they were found and the materials of which they are made.

3. How can hard rocks be worn away?

If you will examine a boulder or other rock surface which has been exposed to air, water, and temperature changes for a considerable period of time, you will note that the surface is beginning to go to pieces. You may find pieces lying on the ground around the stone. Or you may see rock that has become pitted and rough from long exposure. The fact that rocks can be broken up is of great importance, for very little of the material could be removed if it were not prepared by being broken into pieces small enough to be moved. Without the deep layers of fine materials over the surface of the ancient rocks, plants could not exist. Without them there would be no other life. The process by which large rocks

are broken or worn away must be understood before we can continue the reading of the earth's story.



A volcano not only forms new rocks by depositing melted materials but changes the nature of the rocks through which the melted rock flows.

How do heating and cooling break the rock? If a large amount of molten rock escapes through a crack and flows over the ground in a thick layer, it does not cool evenly. The surface of the melted rock loses heat first and contracts, so that vertical cracks appear in it. Such cracks through the layer of cooled rock are called *joints*. The crack through which the molten rock passed was probably formed in the same way.

Sometimes molten rock is pushed up through joints in rocks that are far below the surface of the earth. Since these cracks do not extend to the surface, the rock may spread sidewise in spaces between older layers. If the pressure is great enough, the surface rock may be lifted to form a dome or fold. Since rock cannot stretch, additional deep vertical cracks may appear in near-by rocks.

Later, movements of the surface rock may result in partially closing the opening. Thus you will not be able to see such cracks unless you look very carefully. Yet these cracks are large enough that they are filled with air and water. Also, the roots of plants often grow into the cracks. Thus the rocks are prepared for other forces to break them into smaller pieces. The process by which rocks are broken or worn away is called weathering.

How does ice break up the rock? Most substances contract as they cool, but we have learned that water expands as it changes from liquid to solid. The force of expansion is so tremendous that if some water gets into a crack in the rock and freezes, the ice will act as a wedge and open the crack still wider. This wedge-work of ice, or frozen water, is one

The rate at which waves wear rocks depends upon the hardness of the rocks. Sometimes caves, bridges, and columns are left when soft rocks wear away, leaving layers of hard rock unworn.

of the most important methods of preparing rock to be carried away.

You can find evidence of this work at the foot of rocky cliffs. As the freezing continues through several seasons, huge blocks of stone are broken off. These large pieces fall down the sides and accumulate on lower surfaces. In falling, hard rocks are broken still further as they strike together.

The work of ice is even more noticeable in softer materials, such as sandstone and other water-formed rocks. These rocks are quite porous and collect large amounts of water. As the water freezes, the pressure is exerted all through the rock. It breaks up by crumbling. You may find such a rock still in one piece, but when you pick it up it may fall apart.

Are there other ways of loosening rock? Rock is not a very good conductor of heat, particularly if it contains much air. So the surface of a rock may become heated by the sun, while deeper rock layers receive practically no heat. The surface tends to expand. Strains are thus produced in the rock. After a long period of heating and cooling, the rock finally breaks apart. Evidence of the effect of heat may be

found on the surface of exposed rocks from which thin layers may be peeled.

Roots of plants also exert considerable pressure as they grow in cracks in rocks. Sometimes trees grow out of cracks on solid rock surfaces.

Do air and water aid in weathering? Air contains some water vapor which it carries into cracks too fine for liquid water to enter. Since the interior of the rock may be cool, the water vapor condenses. It is then available later for freezing. In this way air helps break up rock that is too solid for water to enter in other ways. Air also supplies oxygen and carbon dioxide, both of which may act on the rock.

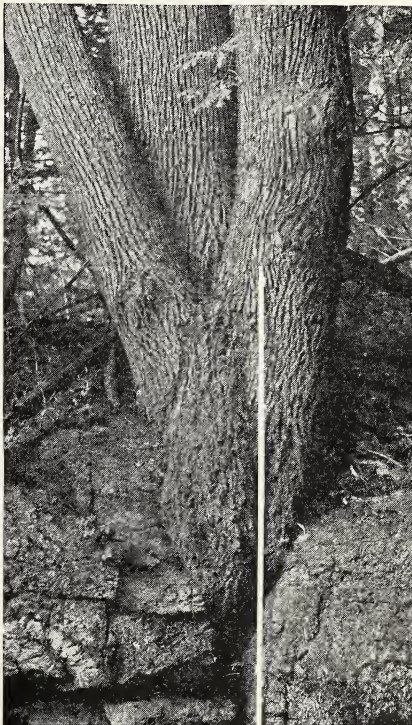
Running water washes out some loose material below solid rock. With the underlying rock gone, large pieces of the solid rock break off. Water also aids in weathering by dissolving some parts of the rock, thus weakening the remaining parts so other weathering processes can complete the process of wearing the rock away.

If a rock contains iron which is moistened with water, oxygen in the air may combine with it to form iron oxide, or rust. You can tell where this has occurred by the presence of reddish, yellowish, or brown colors. Formation of such rusts may soften the rock enough that it will break easily.

In our study of water we found that water containing

The effect of tree roots in rocks is to widen cracks and to break the rock into smaller pieces. Plants are important soil formers.

Courtesy U. S. Bureau of Plant Industry



carbon dioxide will dissolve limestone. Since limestone frequently contains sand or shale mixed with it, this material is left in loose particles after all the soluble [sŏl'ū·b'l, able to dissolve in water] parts have been carried away.

Another important change results from the decay of plants. The substances formed by this decay may act upon certain minerals in the rock to change them into materials that are easily attacked by other weathering processes.

What types of substances can be weathered? From this discussion you might conclude that weathering occurs only in the harder rocks. However, weathering agents may act upon any surface.

Weathering occurs very slowly in surfaces that are bound together by heavy growth of plant roots, such as those in forests or grassy plains. Man may aid the process of weathering by cutting out the timber and plowing the ground. Plowing alone will break the earth into smaller particles which are easily removed. But all the weathering agents will act upon loose and porous materials, as well as upon more compact substances. For example, farmers frequently plow pasture or soil that is inclined to be lumpy during the fall of the year. In the winter, both freezing and thawing and solution loosens these chunks so that they readily break into fine particles with very little additional work before planting in the spring.

——Things to think about——

Write the numbers from 1 to 10 on a piece of paper or in your notebook. The first list contains the subjects of sentences, the second list, the predicates. Match the subjects and predicates. Write after the number of the subject the letter of the predicate which makes a true statement.

Subjects

1. A thick layer of molten rock
2. When molten rock cools, the surface
3. Vertical cracks crossing a layer of rock
4. Breaking and wearing away of rock
5. When water freezes in a crack in a rock, the ice
6. Repeated heating and cooling
7. Plants and even trees
8. Carbon dioxide in water
9. Some parts of a rock
10. Weathering during the winter

Predicates

A. are called joints.
B. grow in cracks in rocks.
C. will not cool evenly.
D. weathers rocks by dissolving them.
E. loses heat first.
F. is called weathering.
G. helps prepare the soil for spring planting.
H. produces strains in rock surfaces.
I. opens the crack wider.
J. may be dissolved by water.

4. How is broken rock moved?

Have you watched the rain as it falls on loose earth and gathers to form little streams of rushing water? Have you seen clouds of dust stirred up by sudden puffs of wind? Or have you seen ice piled many feet high along the shores of lakes or banks of rivers in the spring? Then you know something of the way in which these agents can move substances that are in their way. Perhaps you live where rivers overflow their banks and leave deposits of mud many inches deep,

This scene reminds us of Takakkaw Falls in the Yoho Valley, Canadian Rockies.

or where the wind piles up sand and soil in drifts many feet high. Then you know that the amount of earth materials moved by wind, water, and ice can be very great. Let us see how these forces help to change the earth's surface.

In what direction are materials moved? After the rock has been broken up, it can be moved by any force great enough to carry the pieces. As pieces are separated from higher, exposed rock, they fall and slide until they reach lower supporting materials. Water always flows to lower levels, and thus it is aided in carrying materials by their natural tendency to fall. The wind can pick up particles if they are fine enough. Since the movement of ice is generally downhill, even in the case of glaciers, very little material is actually lifted. In general, then, all agents carrying rock wastes are aided by the force of gravity.

How does ice move materials? When the climate was very much colder than it is now, the snows which fell did not melt rapidly enough during the short warm sea-

Courtesy Great Northern Railway

When glaciers scoop out valleys, the valleys are U-shaped. One glacial valley often enters another at the top. Such a side valley is called a hanging valley. Can you see why?

sons to remove the materials. In this way the piles of snow grew to be many thousands of feet thick. The pressure was very great, so that the lower layers packed, melted slightly, and became ice. If this snow had accumulated and turned to ice without moving, it would have had no great effect on the earth's surface. However, when the pressure became sufficiently great, the whole huge mass began to slide downhill. Such moving ice is called a glacier. Glaciers form U-shaped valleys in mountainous regions.

Glaciers move the rock materials in several ways. If the rock is not too hard, it is scooped out and pushed along in front of the glacier. When the ice melts, this load is left as a hill. Other rocks, picked up as the glacier flows over them,

are ground against the surface of the underlying rock as they are dragged along. Evidence of such movement is found as deep scratches in softer rocks. Loose boulders and other weathered rock fall from the sides of glacier-formed valleys to be carried along on top of the ice. Materials carried in or on the ice are not sorted as they are in streams of water.

When the glacier melts, a mixture of boulders, gravel, sand, and clay is left scattered over the whole region covered by the ice.

Ice also shapes the shores of lakes by expanding as it warms in the spring. The ice is forced out on the shore, thus scraping and pushing large amounts of sand and rock back from the shore line. In northern lakes there are mounds of earth in line with the shore as much as 15 or 20 feet higher than the water level. The materials in these mounds proved that they were formed by the ice.

How does water change the earth's surface? Water running over the surface of the earth carries much loosened material either in solution or by lifting or pushing it along. By far the larger amount is moved in the second way by the running water as it runs over the surface.

Actually, pure water can do very little to rock except to dissolve the materials which hold the rocks together. If the surface has already been broken up, running water will move a wide range of sizes of particles. You can watch water get its load by observing the ground during a rain. The water begins to move toward low places, and continues to still lower levels. At the same time the fine particles of soil are stirred by the falling rain. The flowing water picks them up and moves them short distances. As the volume of water increases, it moves more and more rapidly, carrying the pieces farther. These small streams of water may wash out enough soil to produce large ditches.

Mountain torrents have been known to move rocks weighing many tons. Of course, the water does not actually lift such large boulders but rolls them along the bottom of the stream. Lighter rocks are bounced along. Sand and small

pebbles may be held up in the water because it is constantly being stirred.

The Grand Canyon of the Colorado River has been formed largely by the continual removal of weathered materials. As you look at the canyon, you will see sheer cliffs a thousand or more feet high with slopes at their bases formed from accumulated materials which have broken off from above. The canyon is about 10 miles wide at the rim and about a mile deep.

Keystone View Co. photo

The Grand Canyon of the Colorado River is the greatest of all water-worn valleys. There is no way to describe its size or its beauty so that it can be fully appreciated.

Where the Colorado has side canyons, the rocks between have been left as entire mountains. It is difficult to believe that the river could have removed so much material, but if you were to take the trip down Bright Angel trail to the river's edge, you would quickly note that the water is extremely muddy. You can see large rocks being rolled along as it still continues to deepen the valley by removing materials. Even though the river is carrying large amounts of sand and rock, the formation of this canyon has taken more than two million years.

A river wears away rock and widens and deepens its bed by using material it carries as cutting tools. Where the slope is steep, the water flows rapidly, and the particles are driven with great force against the rocks over which the stream moves. Since the rivers begin on high ground where the slope is greater, the wear is more rapid there. As the water approaches the lowlands and eventually the sea, the slope

Upper S.C.S. Photo, U.S. Dept. of Agriculture; Lower Dominion Experimental Farm Photo

The approaching dust storm blackens the sky. Wind blowing along the earth's surface picks up and carries sand and dust for long distances. Continued dust storms like that shown above may bring to Alberta conditions as shown in the southern Saskatchewan scene below.

grows less and less until there is practically no cutting in the lower parts of the stream. Why?

What changes in the earth's surface are due to wind? Where the climate is very dry and there is a supply of fine rock particles, the wind is continually reworking the surface by moving sand and dust. Also, the wind blowing over lakes and oceans forms waves which carry sand that makes beaches and wears away rocky shores. Thus we see that wind changes the surface in two ways.

Wind has little effect upon very hard rock. Particles of sand, picked up by strong winds and blown against a hard surface, only polish it. If the rock is already softened by weathering, the particles of sand striking the surface may be the final cause of the moving of these pieces.

Most of the material moved by the wind is rolled along the surface. Some material may be lifted for a few feet. In dry regions telegraph and telephone poles have been cut

down by the movement of the sand. Very strong winds may fill the air so thickly with dust that travelers in their automobiles cannot see the road. During these storms, sand drifts like snow, filling small valleys and making mounds. The large drifts are called dunes [dūnz].

Warner Taylor photo

This huge wave, set in motion by a hurricane in the West Indies, is spending its force in breaking on the coast of Maine. Waves wear rocks by tossing sand and gravel against the cliffs.

What other forces change the earth's surface? While most of the weathered materials are moved by falling or by running water or by the wind, there are some changes brought about by the movement of water in seas either where currents exist or where waves beat upon the shores. The currents move rock wastes along the sea bottom, but the most important movement is that of waves in shallow water. Here loose material is moved back and forth until only pieces of similar size are left. This can be observed along beaches. The different types vary from closely packed fine sand to pebble beaches. Since most waves strike the beach at an angle, currents develop along the shore. These currents cause a slow movement of rock particles, which are carried by the moving water.

The general process by which the earth's surface is worn down and the particles removed by all of the agents is called erosion [ė·rō′zhŭn]. When land is eroded, it is worn and broken into smaller pieces which are lifted from their source. Since erosion requires that the particles be removed, the term has been loosely used to include the carrying of the broken particles from one place to another. How is erosion different from weathering?

——Things to think about——

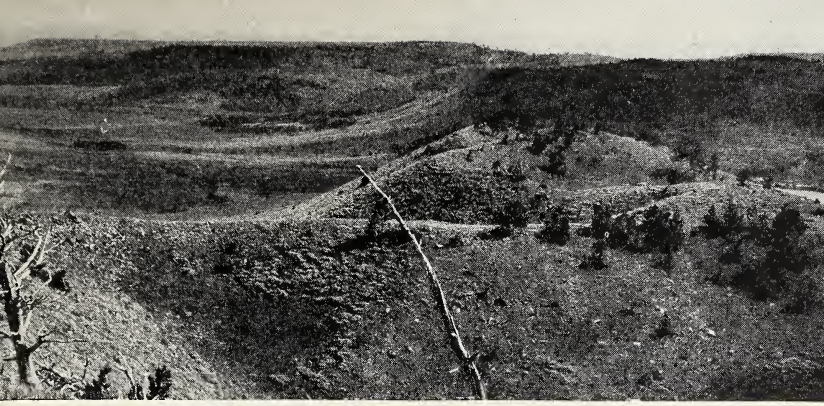
Write the numbers from 1 to 9 on a piece of paper or in your notebook. Complete the following sentences to make true statements. Opposite each number write the word needed to complete the sentence.

If the snow does not melt through the warm season, —1— form. Rock particles are moved by the tendency all things have to —2—. Glaciers form —3— shaped valleys. Running water depends upon its —4— to carry larger rocks. Water can cut canyons in hard rock by the aid of the —5— which it carries. The most important agent now carrying away the soil is —6—. Wind can wear rocks away by the aid of particles of —7—. Movements of large amounts of soil by the wind produces —8— storms. —9— is the whole process of wearing and removing materials from the earth's surface.

5. Where are the rock particles deposited?

It is estimated that the streams of the United States carry about 10 billion tons of eroded materials to the sea each year. This amount of earth would cover the states of Connecticut and Rhode Island with a layer about one foot thick. The streams are only one of the forces acting to change the earth's surface. After weathering and erosion occur, and before the materials reach the ocean, they are deposited, reworked, and deposited again and again. Let us see if we can find and identify any of these deposits where they are now found.

How can we recognize deposits left by glaciers? Because of the method by which glaciers obtain their load, the materials consist of pieces varying in size from fine sand to huge boulders. That part of the load pushed along ahead of the ice is left where the glacier ceased to advance and began to retreat. The materials are generally left in the form of long, rounded hills. If the glacier was narrow, hills are left along the sides as well as in front of the region once covered by ice.



Courtesy U. S. Geological Survey

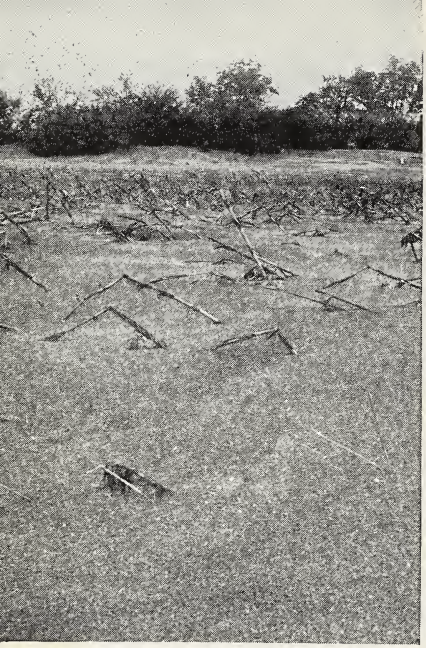
These New York moraines were left thousands of years ago by a great glacier which scooped rock and soil into rolling ridges.

You can tell whether such hills were deposited by the glaciers by looking at the materials in the sides of roads cut through them. Sometimes the materials were left across a valley as a dam. In such cases lakes were formed. The ridges or hills of earth deposited by glaciers are called moraines [mə̇·rānz′].

A large amount of material of all sizes is carried within the glacier. When this part of the load was deposited, it was left scattered over wide areas in layers which may be many feet thick. You can recognize such deposits by the presence of large boulders scattered through mixed materials, generally clay and sand. There is no orderly arrangement and no evidence that the materials were deposited in layers.

The rock particles carried by the glacier are its most effective tools for cutting rock surfaces over which it passes. But as the rock particles cut, they are also ground into extremely fine powder-like material. The streams which are formed by the melting ice carry large amounts of this finely divided rock waste many miles beyond the most advanced edge of the glacier. This waste can be identified as nearly level plains beyond the glacial hills.

Even the materials deposited by glaciers do not stay where they are left, but are reworked again and again, principally



Courtesy U. S. Soil Conservation Service

When water ceases to flow, it deposits the materials it carries. This sand is deposited by a flood to a depth of many feet over a field that only a year before produced 100 bushels of corn per acre. The land is now worthless.

by streams. Most of the soils of the prairie provinces were developed from this source. These soils were not produced by a single glacier. Scientists who have made a special study of glacial deposits tell us that there were a series of these glaciers, the last of which advanced as far south as central Iowa about 25,000 years ago.

Does running water deposit any of its load before reaching the sea? The size and amount of particles which a particular quantity of water can carry depend upon its speed. Anything which tends to reduce the speed of the water will result in loss of some of the load. During a flood, when the stream overflows its banks, the water moves very slowly over the surface, and a great deal of material is deposited. The largest amount is deposited close to the banks where the loss of speed first occurs. In this way old streams build natural levees [lĕv′ēz, mounds near river banks] along their banks.

A similar loss of speed occurs where rapid streams flowing down the sides of a valley meet the flat lands along the bottom. The larger pieces of the load are dropped first, and the finer material is carried until the speed is too slow to hold it. Loss of load in this way results in the formation of fan-shaped outlets with the handle of the fan in the bed of the stream where it emerges from the hills. You can see such

fans on any hillside where the water has cut a tiny valley opening at the bottom on a nearly level surface.

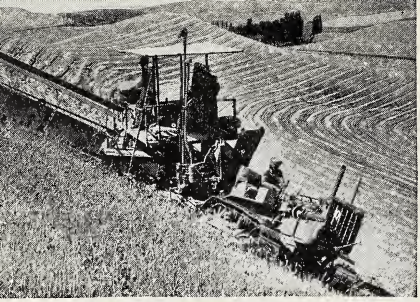
How are stream deposits divided into layers? In the formation of fans we see that running water sorts out its load. We can usually identify deposits made by water from the equal size of the particles found at a given place. Materials deposited by water are called sediments. The lower sediments are the larger, and the size is generally about the same for some distance. The next material is finer; when it is looked at from the side, as in a gravel pit, distinct layers can be seen in it. Such layers are called strata [strā'tȧ].

How are deltas formed? Where a stream empties into a large body of water, it loses its speed and finally stops. All suspended materials are deposited there. In time the sediments may fill the outlet. The stream then overflows its banks and forms new channels through the deposited material. These channels in turn are filled until the whole deposit may be above water level. When this condition is reached, the deposit is called a delta.

As the delta extends out into the lake or sea, the length of the stream is increased. In this manner, the Mississippi River has extended its length several hundred miles. Its delta is one of the largest in the world. All streams do not form deltas at their mouths, however, since their own current or shore currents may scatter the materials.

What becomes of dust carried by the wind? The dust that is blown into the air sometimes settles hundreds of miles away from the point where the original soil was formed. New York and Chicago have been darkened by dust blown from the "dust bowl" states of Kansas, Nebraska, Texas, and Oklahoma.

There are several parts of the United States where enough dust has been blown to form good soil which is farmed. In Kansas, Nebraska, and several of the states in the Pacific Northwest, there are extensive areas over which dust has been deposited. There are also many sections of good farm land, containing wind-deposited soil, which extend from Wis-



Courtesy Spokane Chamber of Commerce

These fertile hills are made up of soil that was deposited by the wind. The hills have the general shape of a snowdrift, gently sloping on the side toward the southwest wind, sharply sloping on the northeast side.

consin and Minnesota to the Gulf along both sides of the Mississippi River.

Dust and sand drift like snow, covering vegetation, filling small valleys, and making ridges. Dust-formed hills often have the shape of snowdrifts. They have a long, sweeping side in the direction of the wind, and a steep, short slope away from the wind. In areas where the wind changes a great deal this form is not so easily seen.

A large amount of dust carried by the wind falls on the surface of streams and lakes, or is blown out over the ocean. Most of that caught by the streams is carried to the sea without being dropped. That falling on lakes slowly settles out and forms deposits which tend to level off the bottoms. Such beds of level material, left after a lake is drained or goes dry, are excellent for farming.

Demonstration. How Does Water Sort Materials?

What to use: Screen, large glass jar, sand, clay.

What to do: Fill the large jar two-thirds full of water. Sift through the coarse screen a mixture of sand and clay, enough to make a half-inch of material in the bottom of the jar. Let the soil settle a few minutes, and repeat the sifting process. Make as many layers as desired. Just at the end of the class period, stir up the materials, and let them settle until the next class period.

What was observed: Does sand settle faster than

clay? Is there some material which is so fine that it does not settle in a class period? Can you see where the first layer ends and the second layer begins? When the materials are stirred up, is there a settling in a different order?

What was learned: Select the correct conclusion.

(*a*) All materials settle from water at the same rate, regardless of size.

(*b*) Clay and sand settle as a mixture which has no layers.

(*c*) Materials settle from water to form layers, the heaviest materials settling fastest.

——Things to think about——

Write the numbers from 1 to 6 on a piece of paper or in your notebook. Opposite each number write the letter before the word or group of words which best completes the sentence.

1. Soils composed of deposits left by glaciers are found in (*a*) Texas (*b*) Iowa (*c*) New Mexico (*d*) Florida.
2. Glaciers leave materials which are (*a*) sorted in layers (*b*) all very finely divided (*c*) useless for farming (*d*) mixed boulders, clay, and sand.
3. Hills left by glaciers are (*a*) cone-shaped (*b*) gently sloping on one side and steep on the other (*c*) generally solid rock (*d*) gently rolling and composed of mixed materials.
4. The material which settles from water fastest are those which are (*a*) finest (*b*) heaviest (*c*) softest (*d*) dissolved.
5. A deposit of land in the ocean at the mouth of a river is (*a*) a dune (*b*) an island (*c*) a delta (*d*) a sand bar.
6. Hills formed from wind-blown sand are (*a*) cone-shaped (*b*) gently sloping on one side and steep on the other (*c*) soon covered by vegetation (*d*) composed of mixed materials.

Courtesy U. S. Bureau of Plant Industry

This is the normal order of soil: on top are the growing and decayed plants, then next comes the black soil filled with roots, then the gravel and broken rock, and last the large rocks.

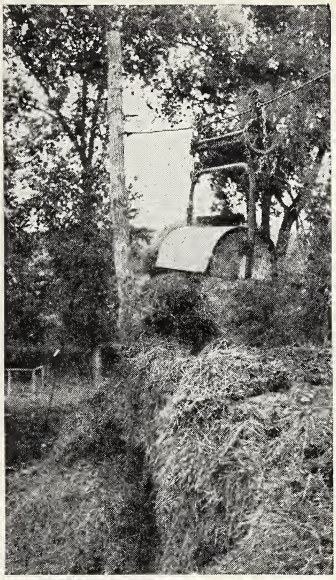
6. How are the rock particles changed into soil?

Preparing the earth for the growth of plants was a long process. In the beginning there was no material like our soil, and today there is still very little soil compared with the amount of the earth's surface covered with rock and water. Erosion processes tend to divide rocks into finer and finer particles, and to reduce rough, mountainous regions to level plains, but if no further changes occurred, the land would be very poor indeed. No farmer would intentionally buy land covered by clay or sand alone, for it would not be easy to produce good crops from it. How, then, does soil differ from other finely divided minerals?

What is soil? Most of the material present in soil is rock. To determine how much rock material is in the soil, heat some soil until all else is removed. Since the rocks do not burn, that which is left is the part supplied by the rocks. But rock wastes alone will not support plant life. It cannot be called a soil until plants will grow in it. Evidently the materials burned or driven off by the heat are necessary for plant growth.

To find out the nature of this material, it is necessary to dig only a few feet in a region such as a forest where man has not changed things. You will find a layer of leaves; below this is a little black soil; then a mixture of soil and gravel; and below that, rock. The entire layer may be only a foot or two deep, although in some areas, such as places covered with glacier or wind deposits, it may be many feet thick.

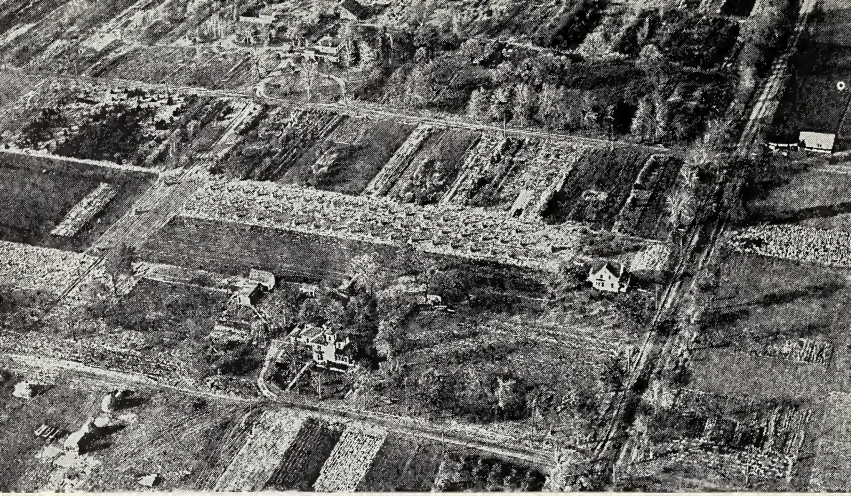
In regions where no vegetation occurs, the black colored layers are not found. This suggests that the plants add certain substances which cause the change. The presence of the leaves on the surface and the roots in the soil explains the origin and nature of this part of the soil. As the vegetable matter decays, the material left mixes with the minerals from the rocks. Such decayed plant material is called humus [hū′mŭs].



The wastes from the barnyard are of great importance in keeping soil fertile. The animal wastes contain nitrogen, while the straw and other plant wastes provide humus (vegetable matter) which is of value in holding air and moisture in the soil.

What substances found in soil are useful for plant growth? As the rock wastes are carried, they are mixed with materials from many sources, and at the same time they are changed, weathered, and parts are dissolved. The principal minerals left are clay and sand.

The sand gives body to the soil so that roots may hold the plant erect. It also serves to keep the soil porous so that the roots may grow through it readily, and water can seep down to provide sufficient moisture.



Kenneth M. Wright photo

Soil which is carried into lakes settles to form flat plains. When the lake is drained or goes dry from lack of water, the land uncovered is excellent for farming.

Clay consists of exceedingly fine particles which provide a large surface area to hold moisture and dissolved chemicals. Because wet clay is sticky, it serves to hold the sand particles together. Too much clay will spoil the soil by holding so much water that little air can reach the roots.

Plants could not live in a soil composed of clay, sand, and water alone. They must have certain elements contained in soluble salts. These salts are largely supplied from the humus. Humus also helps hold the water which would carry away the soluble compounds so much needed by all plants.

How do roots change the soil? The ordinary plant which grows above ground has a root system often as large as the part of the plant we see. These roots branch through the soil, much the same as stems branch above the ground. Some roots grow near the surface of the ground, while others grow very deep.

The roots of plants open up spaces in the soil, and even in the rocks. After a plant dies, water can follow the spaces left by the roots to go deep into the soil. Many times earthworms in making their burrows follow the openings made

by roots. The soil without the work of living things would, after a few years, become packed so hard that plants could not easily get a start. Roots also add vegetable matter which is so valuable that soil cannot be kept in good condition without it.

Roots produce a substance which dissolves rocks. If you plant seeds on a piece of smooth marble, and cover them with blotting paper kept properly moist, the roots will make little marks on the marble. To a lesser extent, other rocks dissolve in the juices made by the roots. Dead roots sometimes make an acid which helps to dissolve some kinds of rocks. The soil may be said to extend down as far as the plant roots go. Where there are roots, the soil is dark, but below where roots go, there is only the color of sand, clay, or rock. The valuable soil is that which has some black soil in it.

Courtesy U. S. Geological Survey

There are many digging animals which speed up the formation of soil. Sometimes, too, they speed up the destruction of soil by running water. In the foreground a prairie dog is shown. Several mounds of earth made by prairie dogs are in the background.

Do animals help in the formation of soil? The woodchuck, or groundhog, digs large holes in the ground, and brings pieces of rock to the surface. Air and water enter the soil through these holes, and act on the rocks to wear them away. The moles and gophers of the East and the ground squirrels of the West do a great deal of digging in the soil. Prairie dogs sometimes dig so many holes in soil that a horse cannot safely walk over the ground. Year after year these digging animals move a great many rocks and particles of soil.

In a different kind of soil, earthworms do much burrowing underground in search of food. Little mounds of soil, called casts, left near small holes in the ground may often be found in meadows and gardens. These casts are the undigested soil that has been left by the earthworms. Holes made by the earthworms also permit water to seep underground to dissolve and loosen other particles of rock.

Demonstration. Which Holds Water Best — Sand or Clay?

What to use: Three beakers, two lamp chimneys, cloth, rubber bands, dry sand and clay, supports.

What to do: Put cloth over the ends of the lamp chimneys, holding it in place with the rubber bands. Fill each lamp chimney half full of soil, one with sand and the other with clay. Put the chimneys on the supports. Pour into each lamp chimney an equal amount of water, and put beakers underneath to catch the water as it runs out. Observe how long it takes the water to run through, and how much is collected in each beaker.

What was observed: Through which chimney does water run faster? How much water runs through each kind of soil? Does the color of the soil change as it is wet?

What was learned: Select the correct conclusion.

(*a*) Sand holds more water than does an equal amount of clay.

(*b*) Clay holds more water than does an equal amount of sand.

(*c*) Equal amounts of sand and clay hold equal amounts of water.

——Things to think about——

Write the numbers from 1 to 12 on a piece of paper or in your notebook. Complete the following sen-

tences to make true statements. Opposite each number write the word needed to complete the sentence.

A mixture of rock and plant wastes is called —1—. A fine, soft soil which holds water well is —2—. —3— gives body to the soil and makes it porous. Soil is colored black by decayed —4— matter in it. —5— move a great deal of soil each year by carrying it to the surface in their digestive organs. When parts of plants decay they form —6—. Holes left by the —7— of dead plants increase the amount of —8— and —9— which can enter the soil. A good soil contains —10—, —11—, and —12—.

Courtesy Sinclair Refining Co.

This ancient monster was a giant relative of the lizards. It was about 25 feet in length. Its name, Stegosaurus, means "roofed lizard" and refers to the peculiar plates on its back.

7. Can life of long ago help us read the story of the earth?

To enjoy stories which are printed, we must be able to read. To understand the stories the earth tells us, we must read the oldest pages of history—the rocks. The rocks tell us that parts of the earth which are land were once deep under water; that regions which today are covered with ice were warm and tropical; that where today there are deserts, rain once fell abundantly. But most interesting of all is the story of the life that once lived upon the earth in times different from ours.

How do we know that once the earth was warmer? Cer-

Courtesy U. S. Geological Survey

One of the interesting types of fossils is petrified wood. These logs have been turned to stone. Petrified wood forms when water carrying mineral soaks into the wood and slowly replaces it.

tain kinds of plants grow only in warm regions; others grow only where it is cold. Some of the plants of the past ages fell to the ground and were buried under layers of mud in ancient swamps. These trees and plants are somewhat like those which grow in our warm countries today. The material left behind formed coal. By studying the plants which have left remains in the coal, and by studying the prints of their leaves in mud which has hardened into rocks, we can tell how they grew.

Coal is found in many places where tropical plants could not possibly grow today. In the northern states there are beds of coal underground. Even in Alaska there is coal which was formed from tropical plants. Scientists think that in order for coal to have formed in these localities, the climate there must have been very warm at one time.

There are many kinds of animals that live only in warm countries. Yet there are bones of such animals in the dry, cold deserts of Mongolia, in the Dakotas, and in many other places now too cold for such animals. Small animals called

corals grow only in warm shallow water. When they die their shells form rocks. Today coral rock is found in regions as far north of the tropics as Greenland, most of which is now covered with ice. Such evidence proves that all of these places once had a tropical climate.

Trees that are gradually soaked full of water carrying minerals change to rock, forming petrified wood. There are full-sized petrified trees in Yellowstone National Park and in Arizona. From a study of petrified wood we can tell not only what kinds of trees grew in different places but also the past climate of these places.

Did water once cover what is now land? The marks left by water are just as plain as the marks left by glaciers. Stones that are worn smooth have been carried by water and have been polished by being rubbed against other stones. Only water will make pebbles smooth as they are rubbed against each other.

We have seen how material deposited by water is sorted into layers. There are many kinds of rocks in layers which are found hundreds of feet below the surface of the land. This fact is proof that water once covered the land and formed this type of rock.

Animals and plants which grow in salt water are different from those which grow in fresh water. Remains of plants and animals that once lived in the water fell to the bottom of the lake or ocean and were buried in the soil which later became rock. By examining these rocks, it is possible to tell whether they were formed in lakes, in the ocean, or in rivers.

Where there are beaches, you can easily find where the sand was washed by water. The waves cut into the rocks, leaving marks which are easy to recognize. Ancient beaches with pebbles, sand, and rocks worn smooth by waves have been found high up on hillsides, even in desert countries.

Because the land is constantly rising and sinking, though very slowly, dry land sinks below the ocean, and the ocean

Courtesy Science Museum of St. Paul Institute

One of these animals is a birdlike reptile, the other a reptile-like bird. The bird picture was taken from a model of one of the first birds on earth. It has teeth and a jointed tail.

bottom becomes dry land. Some parts of the earth, though, probably have never changed.

What can we discover about the story of life on the earth? The oldest rocks found on the earth today do not show any evidence that in the most ancient times there was life on the earth. Yet today there are upon the earth almost a million different kinds of animals, including the insects, sponges, frogs, reptiles, birds, and all the others.

Scientists have found that the earliest life that appeared upon the earth lived in the ocean. The first plants and animals were very simple. Gradually larger forms of life developed.

Changes in the development of life on the earth took place very gradually. This fact can be seen by comparing the birds of today with the remains of the birds of the past. We know that birds are somewhat like reptiles, for they have scales on their feet, and their bones are somewhat like those of reptiles. Bones of ancient birds have been found which show how modern birds probably developed from reptiles.

The first flying birdlike animal was a reptile. This reptile had no feathers, but used weblike wings. Bones of an an-

cient bird have been found which are much like those of the ancient reptile. This ancient bird had a mouth with teeth like those of a lizard, and had feathers like a bird. It had a long, jointed tail with feathers on it. The birds of today show some resemblance to the first birdlike reptile.

By fitting bones together, scientists know how these ancient animals looked. They have made models from the bones.

The story of plants is just as clear as the story of the animals, but perhaps not so interesting. Many remains of ancient animals and plants have been found in recent years. We now know nearly as much about the life of the past ages as people formerly knew about life in their own times.

Demonstration. What Is a Fossil?

What to use: Leaves, clay, burner, ring stand.

What to do: Mix clay with water so that it is quite stiff. Flatten one lump of clay against a board. On the flat surface place a leaf. Above the leaf press another flattened lump of clay, so that the two lumps stick together. Bake them over the flame on a screen. Break the lumps apart and examine the inner surfaces. You can also make a print of your hand in the clay by pressing the hand into the soft clay and permitting the clay to dry.

What was observed: Does clay change as it is heated? Does the leaf change as it is heated? Can you see clearly the veins of the leaf imprinted on the clay?

What was learned: Select the correct conclusion.

(*a*) Fossils are always made by baking leaves in clay.

(*b*) A fossil is the imprint of something that was once alive, or parts of ancient plants or animals preserved in rocks or soil.

(*c*) Leaves may be baked in clay without burning them.

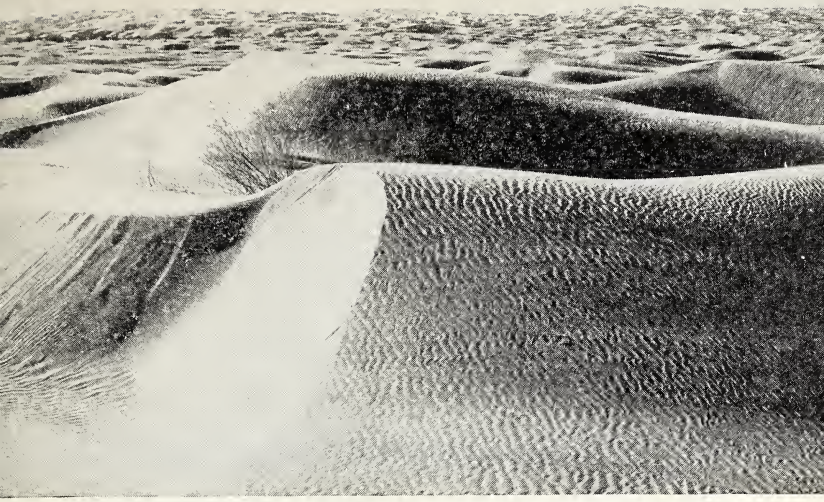
——Things to think about——

Write the numbers from 1 to 5 on a piece of paper or in your notebook. Opposite each number write the letter before the word or group of words which best completes the sentence.

1. Coal was formed in large amounts where the climate was (*a*) warm (*b*) cool (*c*) temperate.
2. Coal beds are found today (*a*) only in hot countries (*b*) only in cold countries (*c*) in many types of climates.
3. The ancient, huge animals which lived when coal was being formed were like (*a*) common animals (*b*) reptiles (*c*) birds.
4. Water-deposited materials are found (*a*) in layers (*b*) mixed up (*c*) scattered evenly on other rocks.
5. We can tell that water once covered parts of the land by finding (*a*) dry beaches (*b*) animal tracks (*c*) fossils.

A Review of the Unit

The surface of the earth is constantly changing. By studying the rocks carefully, we see that they are composed of substances which were brought together under widely varying conditions. From the rocks we can learn something of the forces that are working to change the earth's surface. Some of the rocks were formed from materials sorted by wind and water; others were formed by great heat; still others are changed forms of the first two types. Rocks are continually being worn down by the action of water, wind, and changes of temperature. Weathered rocks are moved to distant resting places by ice, water, and wind, all of which are aided by the tendency all substances have to fall. Deposited rock wastes are slowly changed to soil or converted into hard rock. The conditions under which the deposits were made can be read from the presence of fossils of plants and animals.



Frasher's Photos, Pomona, California

Sand drifts in the desert forming dunes of beautiful patterns. These drifts of sand kill vegetation by covering it completely.

An exercise in thinking

Below are two groups of sentences. The first group contains principles, which are large general ideas. Each sentence in the second group contains an idea related in some way to one of the principles in the first group. Write the numbers from 1 to 30 on a piece of paper or in your notebook. Find the principle which best explains the idea in the second list. Then after the number on your paper write the letter before the related principle.

Example: Clay is formed from weathered granite rocks.

The correct letter for the example sentence is ***D*** *because the presence of clay shows that there was a period of erosion and soil formation.*

List of principles

A. The force which causes melted rock to flow from volcanoes is related to earthquakes and earth movement.

B. Running water wears away and carries rock materials.

C. Materials carried by water and wind settle in still places.

D. Before erosion occurs, rocks are generally broken by weathering into particles small enough to be moved.

E. Glaciers grind up and carry rock material.

F. Changes in the earth's surface, and development of life upon the earth have left their stories in rocks.

G. Soil is formed by weathering, erosion, and living things.

List of related ideas

1. Earthquakes frequently occur where mountains are being formed.
2. Heating and cooling cause rocks to crumble.
3. Limestone rock contains ancient sea shells.
4. There are sand dunes along the Atlantic Coast.
5. Skeletons of some reptiles and birds are similar.
6. At the bottom of cliffs there is usually loose material on which plants grow.
7. There is a delta at the mouth of the Mississippi.
8. Black soil is usually only a few inches deep.
9. The Grand Canyon is a deep valley in solid rock.
10. There are remains and imprints of plants and animals called fossils.
11. Many western mountain peaks were formed by volcanoes.
12. Earthworms have been active in improving soil.
13. Sudden shifting of the earth's crust may take place either up and down or sidewise.
14. One common kind of soil which holds water is clay.
15. Slipping of the earth's crust melts rock and causes earthquakes.
16. The Red River is red because it is full of sediment.
17. Decaying plant material forms humus.
18. Lakes behind dams fill up with mud.

19. Glacial valleys are *U*-shaped.

20. Ice, water, heat, and wind form soil.

21. Before there were people upon the earth, there were giant reptiles.

22. The most important erosive force is running water.

23. Idaho, Oregon, Washington, and California contain rock formed from lava.

24. Dust has been carried from Oklahoma to New York.

Alberta Government Photo.

Model of a dinosaur on St. George's Island, Calgary. It lived in swamps, floated in the water, and ate plants.

25. Rounded and irregular hills may be formed by glaciers.

26. Water is able to cut deep canyons by using the rocks it carries as tools.

27. The particles of rock carried by water cut into rocks in the stream.

28. Plowed ground erodes rapidly.

29. Earthquakes frequently occur at the same time as volcanic eruptions.

30. There are rocks showing deep scratches in the northern states.

An exercise to test yourself

Write the numbers from 1 to 10 on a piece of paper or in your notebook. Opposite each number write the letter before the word or group of words which best completes the sentence. Some sentences have more than one correct answer.

1. Glaciers move large masses of material which are left (*a*) sorted as to size of particle (*b*) as level plains (*c*) as a mixture of boulders, sand, and clay.

2. Well-sorted gravel was deposited by (*a*) ice (*b*) water (*c*) wind.

3. Volcanic mountains are (*a*) cone-shaped (*b*) broad and rounded (*c*) composed of soft materials.

4. A rock which was not formed from materials deposited by running water is (*a*) gneiss (*b*) shale (*c*) limestone.

5. The best soil for the growth of plants consists of (*a*) sand, gravel, and clay (*b*) sand, clay, and decaying vegetation (*c*) clay and barnyard wastes.

6. *U*-shaped valleys are formed by (*a*) ice (*b*) water (*c*) volcanic action.

7. As the forces and agents of weathering and erosion continue, the land (*a*) becomes more rough (*b*) has better drainage (*c*) approaches a level plain.

8. Erosion occurs most readily in (*a*) rocks that have been heated and cooled to form a solid block (*b*) hills whose surfaces have been loosened (*c*) areas that are nearly level.

9. Sandstone was deposited by (*a*) running water (*b*) glaciers (*c*) volcanoes.

10. Rocks are composed of (*a*) mixture of elements (*b*) a simple compound (*c*) different minerals.

Some things to explain

1. Why do we think of rocks as being permanent?

2. How do we know that the earth is very old?

3. What is the most common surface rock? Why is it so common?

4. Why do we say that running water is the most important force changing the earth?

5. Can you explain why separate deposits of pure clay and pure sand are found close together when both are formed from weathered granite?

6. How does all life depend upon soil?

7. Can you explain how rocks weighing as much as 20 tons are found at the mouths of mountain streams among well-sorted gravel?

8. Why is erosion dangerous to farm lands?

9. If mountains in the past have been worn down, why do we still have mountains?

10. Why does some sandstone contain fine particles, while other sandstones are made up of coarse particles?

Some good books to read

Croneis, C. A. and Krumbein, W. C., *Down to Earth*
Daly, Reginald A., *Our Mobile Earth*
Fenton, C. L., *Our Amazing Earth*
Fenton, C. L., *Life Long Ago*
Hawkeworth, H., *Strange Adventures of a Pebble*
Hawkins, A. C., *Book of Minerals*
Hobbs, W. H., *Earthquakes*
Jeans, Sir James, *The Universe Around Us*
Reed, W. M., *The Earth for Sam*
Russell, I. C., *Volcanoes of North America*
Small, S. A., *The Boy's Book of the Earth*

Lower Milk River, Alberta. Courtesy National Museum of Canada.

UNIT FOUR-B

WHAT CHANGES HAVE TAKEN PLACE IN THE EARTH'S SURFACE?

Few people live long enough to note and learn the causes of the changes that take place in the earth upon which they live. It has become a habit to use expressions such as "as old as the hills," "the changeless rocks," "as enduring as the mountains." Yet these expressions indicate only that we have failed to observe for a sufficiently long time the changes that undoubtedly have taken place in the hills, rocks, and mountains. If a person could spend one day on earth in each 1000 years, and make as many visits as there are days in 100 years, he would note many changes in the 36½ million years during which he was making his observations. In fact, he might well use another common expression: "Things have changed so that I hardly know the old place."

Over any period of millions of years mountains form and wear away; rivers cut valleys which eventually become plains; the ocean covers the land; and the bottom of the ocean rises to form solid ground. Rocks themselves change form, are worn away, and the materials once again are formed into new rocks.

Plants and animals change to fit the changing conditions under which they live. The swamps become plains. Cattails and other swamp plants die and provide food for grasses and trees which grow in their place. As fish and shellfish in the ocean die, their remains may be left in rocks. These rocks later are found high on mountaintops after the land rises.

The volcanoes become cold, and their once-flaming craters are filled with glacial snow and ice. The slow-creeping water dissolves its way into tiny cracks, and enlarges them to form caves miles in extent. Rivers drain lakes which were once larger than most states of our nation. Ice grinds its slow way halfway across a continent, then melts to leave behind beautiful lakes and rolling hills such as are found in our northern states.

The forces which bring about these changes are familiar to us all—wind, running water, gravity, heat, and solution. Yet it is a fascinating story to learn how these apparently small forces can produce the enormous changes that we know must have taken place in our earth in past ages.

Courtesy New York State Museum

These glass models of sponges show a type of animal that lived in the sea perhaps 30 million years ago. When their skeletons are found in rocks on dry land, what is indicated?

1. What forces raise and lower the land?

Usually people are aware of only the sudden and violent movements of the earth—those connected with earthquakes or with volcanoes. The slower and more extensive raising and lowering of the surface of the earth last over long periods of time—periods longer than any individual can observe.

How do we know that the earth's surfaces are lifted or lowered? If all the ice should melt from near the North and South Poles, there would be more water in the ocean, and the water would cover more of the land. If more ice were frozen in the glaciers, there would be less water to fill the ocean and more land would be exposed. But on the average, the level of the ocean remains constant for thousands of years.

Yet today it is possible to find on hillsides, far removed from any ocean, old beaches and cliffs that were formed by the cutting action of waves. You might think that these waves were in a large lake if you did not find on these old beaches

shells of animals that live only in salt water. Since there are very few salty lakes in the world, the work must have been done by ocean waves.

Near Pompeii, in Italy, an ancient temple, built on land 1800 years before, was exposed by digging. It was found that certain sea animals had bored holes in its marble columns at a height of many feet. This temple not only had been lowered into the ocean by the sinking land, but had been raised above the sea by rising land. Then soil had been deposited from the ashes of the volcano Vesuvius, covering the temple.

There are many high mountains of rocks built from the shells of animals which live only in salt water. Such limestone rocks are common in many parts of the United States.

When land along the seacoast is sinking, it is natural that the lower places should fill with water first. Along our Atlantic Coast there are old river valleys which have disappeared under the ocean. The Hudson River has been traced under water by measuring the depth of the ocean for more than 100 miles southward from New York Harbor. Many of the best harbors result from ocean water filling valleys as the land sinks.

The land may rise or sink far inland. In Missouri a large area of land, once part of the flood plain of the Mississippi River, has sunk and is now covered by a lake. There are still treetops rising above the water of the lake.

Does the earth's surface move sidewise? The earth's surface moves sidewise enough that the movement can be measured. Scientists of the United States Geological Survey find that this sidewise movement of the land can be noticed in the mountains along the Pacific Coast.

What causes earth movement? It is possible that the earth, in cooling very gradually, is contracting as it cools. If this theory is true, the interior of the earth is gradually shrinking, leaving the surface of the earth too large to fit. As the interior shrinks, the surface settles, shifts, and tilts, causing some parts to be raised, while other parts are lowered. If

Photo E. Geyer, Aletschwald, Switzerland

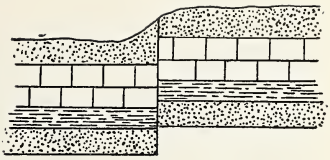
Glaciers not only weight down the earth but move huge masses of rock materials. Here two glaciers have joined, showing their dividing line by the presence of rock materials each carries along its edge.

you have seen the wrinkled skin of a baked apple which shrank from being cooked, you can picture the way the earth's surface folds.

It is possible that some movement of the earth's surface is caused by melted rock flowing upward from the interior of the earth, pressing up beneath the rocks near the surface and lifting them.

It is also possible that as materials are moved on the surface of the earth by rivers and glaciers they cause the surface of the earth to become heavier in some places than in others. These materials, pressing down on the lower layers of rock, force other lighter materials near-by to move to make room as they settle. The lighter materials may move sidewise for a time, but will also be forced upward by the crowding of the heavier rocks. Movement of this type is believed to extend not deeper than 50 or 100 miles into the earth. Below

that depth rocks are believed to be of uniformly heavy material.



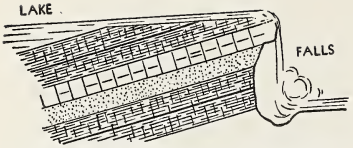
A crack in rocks along which movement takes place is called a fault. Layers of rock do not "match up" at faults.

None of these theories may be right, or all may be right to some extent. It is known that gravity—the pull of the earth upon all materials which make it up—provides one great force causing the settling movement of rocks. Energy released from changes going on in the interior of the earth may provide another force causing surface movement.

What are the results of surface movement? One of the immediate results of movement of the earth's crust is an earthquake. Usually an earthquake is caused by a sudden slipping of two rock surfaces against each other. There are many long cracks, called faults, in the surface of the earth. Some faults are hundreds of miles long. Even a slight slipping, as little as half an inch, of the rocks on one side of such a fault is enough to cause a severe earthquake. The shaking of the earth's surface usually lasts only a few seconds, but in that time houses may be shaken down and much other damage done.

Earthquakes may result from slipping of rocks deep in the earth. It is possible to locate these earthquakes quite exactly by use of accurate recording instruments, although no evidence of slipping may be seen at the surface.

Earthquakes may cause landslides or other movement of soil. Sometimes underground streams which supply water to springs may be lost in deep cracks in the rock, and the springs become dry. Where people have laid water pipes, movement of the earth may break the pipes. Gas and oil pipes are sources of danger, for if they break, destructive fires may result. Cities in earthquake regions are now being made earthquake-proof. Pipes and bridges are built to withstand strains. Houses are made strong enough that they will not fall and injure people.



Tilting of rock layers is a frequent cause of waterfalls. Where surface rock has been removed, it is easy to identify the layers originally deposited in a level position.

Another effect of earth movement is the tilting of layers of rock. You know that materials settle from water to form rocks that are fairly level. Yet as a result of movement of the earth's surface, such layers of rock may be tilted until they stand on end, or they may be folded in the shape of a U, either right side up or inverted.

Near the ocean tidal waves may be set up by sudden shifting of the earth's surface. A sudden high wave sweeping over the land may destroy docks, wreck boats, and drown people.

Is raising of the land surface important to us? You know that water is constantly wearing away the land and carrying the materials into the ocean. You may wonder if some day all the land will be made level, so that the waves of the ocean can carry it away to leave only water on the earth. For millions of years processes of wearing away the land have been going on, yet the forces which cause land to rise have kept a fairly large part of the earth's surface as dry land. At present about one-fourth of the earth is above the sea.

——Things to think about——

Complete the following sentences. Do not write in this book.

The existence of limestone at a high elevation is evidence that the land has —1—. A valley filled with water is evidence that the land is —2—. Rocks composed of layers are usually formed under —3—, and are level when formed. Such rocks may be —4—, or —5— into a U shape. A sudden movement of the earth's surface causes —6—. It is believed that movement of the earth's surface does not extend more than —7—

Courtesy U. S. Geological Survey

This is a volcanic dike. Melted rock under pressure was forced upward into a crack in softer layers of rock, which now are partly worn away.

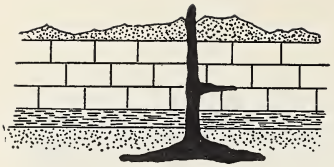
miles below the surface. The weight of surface rocks is changed by movement of materials by —8— water and by —9—.

——Science activity for fun——

Take a walk in some area not covered with houses or fields, and observe the rocks and soil, particularly in cuts along roads, along stream banks, and along cliffs. See if you can find rocks which have been folded, or rocks which show action of water. Can you find rocks containing shells of animals?

2. How do rocks indicate surface changes?

Almost any rock that you might pick up gives you evidence upon which you can base some reasonable conclusion concerning surface changes that have taken place in the past. If you can find certain rock formations, not too badly broken to recognize, then you may develop a fairly complete story from a single observation.



The upper rock has eroded, leaving the dike exposed. The sill underground was formed by a sidewise flow in another crack in the original rocks.

What surface changes are indicated by once-melted rocks? There is a large group of rocks which have been formed by cooling directly from the melted state. These are the igneous [ĭg′nē·ŭs] rocks. There are two common types of igneous rocks: the granites and the basalts [bȧ·sôltz′]. A number of interesting clues regarding changes of the earth's surface may be found in a study of these rocks.

Igneous rocks are made up of crystals. If the crystals are large and coarse, as are those of granite, it is probable that the rock was formed deep in the earth, and cooled slowly under pressure. If the crystals are fine-grained, it is probable that the rocks cooled rapidly at the surface of the earth. Some igneous rocks contain both fine and coarse crystals, which indicates that the rocks started cooling underground and then flowed to the surface. One kind of rock, obsidian, cooled so rapidly that it has no crystalline structure at all, but looks like glass.

The basalt rocks contain iron and other chemicals not found in granite. Basalt rocks often cool to form six-sided, closely clustered columns, such as are found along the Palisades of the Hudson River. When you see such a rock formation, you know that the rocks are igneous, and were probably cooled after they flowed to the surface of the earth.

When you find a coarse-grained granite at the surface of the earth, you can conclude that it was formed beneath the surface but has been exposed by erosion of the overlying rocks.

Sometimes melted rock does not flow to the surface, but spreads underground. If the rock flows through a crack horizontally and cools, the resulting layer of igneous rock is called a sill. If the melted rock flows through a vertical crack, it forms a wall between the older layers of rock, and is called a dike. When the surrounding rocks are eroded

away, the dike may remain as a huge wall of forbidding rock. Small dikes may appear merely as streaks in other rocks.

Lava is the melted rock that issues from volcanoes. If it flows over the earth, it covers other rocks. Some men digging a well through igneous rock once came upon a layer of sand in which scorched tree trunks were buried. You can easily understand what had happened there long ago. In the Pacific Coast and Mountain states there are many evidences of the flowing action of igneous rocks.

Keystone View Co. photo

Standing rock, Wisconsin Dells, was left behind when the softer rock weathered away. The capstone, or top layer of rock, is much harder than the rock in the column beneath it.

What stories are told by water-formed rocks? The sedimentary [sĕd′ĭ·mĕn′tȧ·rĭ] rocks were formed under water. They consist either of materials deposited from water or of skeletons and shells of animals. Sea animals form skeletons by taking the necessary minerals from the sea water in which they live.

Some sedimentary rocks consist of coarse and fine materials mixed together. These rocks, called conglomerates [kŏn·glŏm′ĕr·ĭt], must have been formed at the bottom of a slope where coarse materials of which they are made were carried by a fast-flowing stream. We know that sluggish streams cannot carry pebbles any distance.

If the rock is a sandstone made of well-sorted sand particles, it is reasonable to conclude that they were deposited in a stream bed or along a shore. If the particles are very fine, it is likely that the water carried the sand a long distance before it settled.

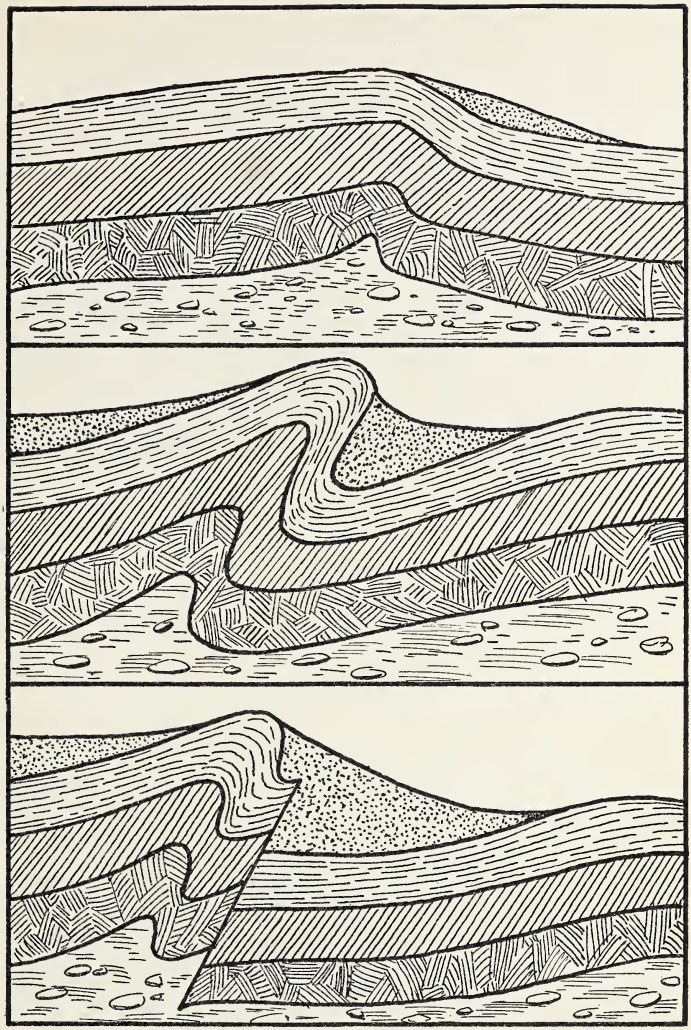
If the grains are still finer and are made of materials which stick together when wet, it is likely that they were formed still farther out from the shore. These fine particles are usually clay and form shale rocks. If a shale has black streaks in it, it was probably formed where there was vegetation, for black soils contain vegetable material.

It is sometimes possible to find places where there are sudden changes in the types of sedimentary rocks in different layers. Such sudden changes indicate a similar change in the surface of the earth. If a layer of wind-blown sand is covered by a layer of shale, it is an indication that the land was lowered beneath the water or that there was a flood when the shale was formed. If there is a layer of conglomerate above the shale, we can assume that near-by regions were elevated to make possible the fast-flowing streams necessary to form such deposits.

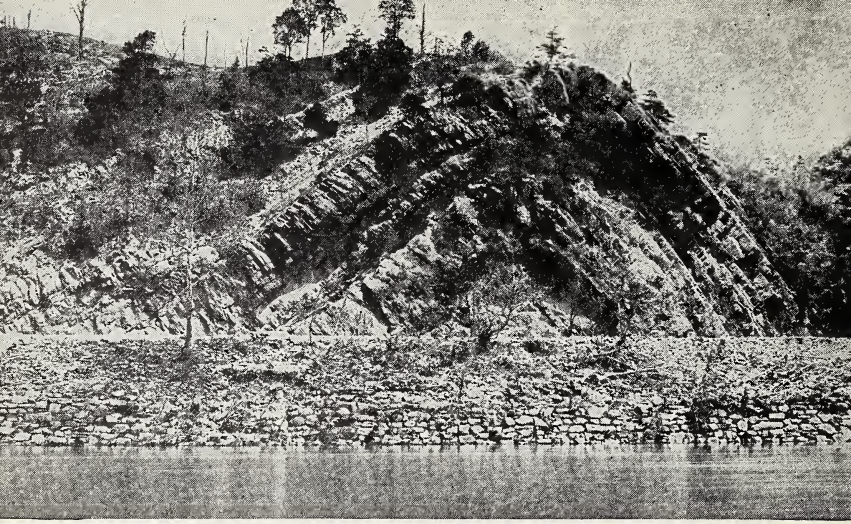
Sometimes sedimentary rocks of one type are tilted sharply, and sedimentary rocks of another type lie in horizontal layers across the ends of the first layers.

The normal order in which the materials for forming sedimentary rocks are deposited is first the pebbles, then the coarse sand, then the fine sand, and finally the clay. If the sand has sunk beneath the ocean, the upper layer of rock may be limestone. As a highland is worn away, the slope of the stream becomes less and less steep, and materials are deposited in normal order. If the land is raised during the process, the order may start over again before the first process is complete. If the land sinks below the ocean, limestone may be deposited on coarse sandstone or conglomerate.

How have rocks changed form? Rocks may be changed in form by the action of heat, water, or pressure. All three of these forces may work together to change rocks. Limestone may be changed into marble. Changes of this kind usually take place below the surface. Shale similarly may be changed into slate. If the slate is black, the shale probably was formed from clay materials containing vegetation. The changes which take place in rocks may be compared to the changes produced by baking clay to form bricks. Rocks



Folding of rocks goes on very slowly. The pressure of the shifting crust of the earth causes a fold to start (*top*), then it folds more sharply (*center*), and finally may fault—that is, crack and slip (*bottom*). The Rocky Mountains were produced by a similar folding movement.



Courtesy U. S. Geological Survey

Rocks deposited under water form fairly level and regular layers. Movement of the earth's crust at some later time may cause them to bend, crack, and fold.

which have been changed in form are called metamorphic [mĕt′ȧ·môr′fĭk] rocks.

How do rocks indicate surface movement? If a sill or dike of igneous rock is broken off sharply and then continues on a different level, we have proof that the surface of the earth moved after the flow of molten rock ceased.

In areas where the surface rocks do not indicate that the land has moved, the reports of well drillers are of value. Samples obtained from wells may show the presence of certain kinds of rocks over areas hundreds of miles in extent. In drilling for oil in the Turner Valley section of Alberta, it was found that the much sought Madison limestone, in which oil had been discovered, was encountered at various depths. The mapping of these various depths of the limestone strata indicated where new oil beds were likely to be found. Since the limestone was probably deposited on the level, it is apparent that there must have been widespread movement of the earth's surface at some time since the rock was formed.

While layers of rock are frequently tilted by pressure, it is more common to find that they are bent. Clearly, it is impossible for a rigid rock to bend suddenly. Even when bending is very gradual, cracks appear in the rocks. It is possible, if there is enough pressure and if the movement is gradual enough, that some rocks will actually bend without cracking. Close examination of folded sedimentary rocks will show whether they bend or crack as they are acted upon by the changing surface of the earth. Such careful study of clues is essential if we are to know what changes have taken place in the surface of the earth.

——Things to think about——

Complete the following sentences. Do not write in this book.

Rocks which have changed in form are —1— rocks; those which cooled from the melted state are —2— rocks; and those which were deposited from water are —3— rocks. Water-deposited rocks are formed from —4— or from the skeletons or —5— of animals. If conglomerate rock overlies shale, a near-by place was —6—. Walls of igneous rock between other rock layers are called —7—. Large crystals are formed in rocks from —8— cooling. —9— rocks contain iron and other minerals.

——Science activity for fun——

If you started a rock collection last year, add to it and improve it. If you have no collection, start one, and classify all your rocks into the three classes mentioned in this problem.

3. How are mountains formed?

Just what is a mountain? Is it a hill of a certain height above sea level, or is it a hill that is considerably higher than any other near-by elevation, regardless of its height above

Courtesy U. S. Department of the Interior

Explosions in a volcano cause formation of lava fountains. This active volcano in Hawaii frequently tosses lava into the air.

sea level? Actually, there is no single definition according to size that will separate mountains from hills. In fairly level sections mountains may be hills only a thousand feet high, while in elevated sections mountains may be several thousand feet high, and elevations of a thousand feet may be called foothills. Mountains are usually narrow on top, rather than broad and flat.

Mountains are generally formed by the same forces that raise and lower the land, and by the action of running water. The most common mountains are formed by volcanic action or by the folding of surface layers of rocks or by faulting and slipping of layers of rock or by erosion of elevated plains.

How do volcanoes form mountains? At depths of from 10 to 50 or 100 miles beneath the surface of the earth, pockets of melted rock form. This melted rock, called magma, is formed from rock already heated underground, when the pressure on it is released. Pressure may be released when the upper rocks are worn away, when they are folded, or when they are uplifted. We do not know just why some underground rocks become very hot.

The melted rock flows slowly underground, melting or heating near-by rocks as it goes. These rock flows may not always reach the surface, but may still push surface rocks upward, causing them to form mountains. A mountain produced by the lifting force of melted rock may be made up of folded layers of surface rock.

The usual volcanic mountain is made up of materials which come to the surface of the earth and escape through an opening to form a more or less cone-shaped peak. The materials of which such mountains are made are usually lava or ash. At the top of the volcano is a pit or opening called a crater.

Courtesy Northern Pacific Railway

The Rocky Mountains have resulted from erosion of complex, folded rocks. Many of the ranges in these mountains are rugged.

When the volcano is active, the crater is full of melted rock. When a volcano is quiet, the lava changes to solid rock, and there may be no evidences of activity at all. In the craters of other volcanic peaks, jets of steam may be found issuing from the rocks.

Many of the most magnificent peaks in the United States are ancient volcanoes. Some of them—Mount Rainier and Mount Baker, in the State of Washington; Mount Hood, in Oregon; and Mount Shasta, in northern California—have been active within the past few million years. It is not known whether they may ever become active again or not. The last volcanic eruption in the United States was that of Mount Lassen in northern California in 1916.

How does folding form mountains? The folding caused by the pressure of upflowing melted rock may produce large mountain ranges, such as the Canadian Coast Range, the Sierra Nevadas, and the Green Mountains.

Other surface rocks may be caused to fold by the sidewise force of other, heavier rock layers. If you lay a piece of canvas on a smooth table top, you can make the middle of the canvas rise up in a hump or fold by pressing with your hands on its edges. It is believed that the Appalachian Mountains were originally formed by such a huge folding action.

Keystone View Co. photo

The Wasatch Mountains of Utah are block mountains. The blocks have been eroded so that their edges are no longer sharply defined. The pressure and heat of the shifting of the earth's crust changes the rocks.

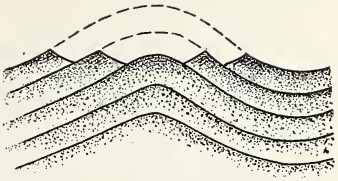
How does faulting produce mountains? Since a fault is a displacement of masses of rock caused by rocks slipping along a crack, you can see that if the displacement is great enough, part of the mass of rock may be elevated to make a mountain. One mass of rock may be moved so far that it is pushed up over the edge of the adjoining rocks. In such a case, one side of the mountain forms a gradual slope, while the other side forms an abrupt cliff. Such a formation is found in the Rocky Mountains of Colorado. The Wasatch Mountains of Utah were formed by erosion of faulted mountains.

The process of faulting may be compared to the tilting of blocks of concrete in a sidewalk where it has been broken and made uneven. The block mountains actually resemble such concrete blocks in their slope and position.

How are mountains formed by erosion? Erosion, which is the wearing away of the land, may form mountains only when the land is already high above sea level. Bordering the Grand Canyon are mountains left between valleys worn by running water. They are remains of the high plateau through which the Colorado River has cut its way.

When melted rock has pushed its way upward beneath layers of softer sedimentary rock, the softer rock may be

eroded, leaving behind ridges, domes, or mountains of igneous rocks. Sometimes these formations are of strange shapes and are called by fanciful names, such as Devil's Towers.



This diagram shows in a simple way the method by which the Appalachians were formed. The dotted lines represent the original folded rocks. The remaining ridges run roughly parallel to each other.

Erosion occurs on all types of mountains. The huge folds which originally made up the Appalachian Mountains have been eroded, until today most of the ancient mountains are gone. There remain only comparatively low ridges formed by the edges of the harder layers of rock which were exposed by erosion. These ridges run roughly parallel to each other. Between them are trough-like valleys resulting from erosion of the softer layers of rock.

It is an interesting experience to climb to the top of a mountain formed by erosion of an ancient plateau. The region seems very rugged as one scrambles up the mountain from the valley. Then all at once it seems to become level as one looks across the distant mountaintops. One can see, in the small remaining land surfaces making up the tops of the mountains, the last remains of the original surface of the plateau.

Are mountains always formed by one process? You have seen that the pressure of melted rocks may cause folds, which in turn may be worn away by water and ice. Rock layers which have once folded may fold again, then may be eroded, and finally may be covered over by lava from a volcano. No matter what combination of forces you may be able to think of as being capable of forming mountains, it is possible that somewhere on earth a mountain has been formed by such forces.

The earth is old enough that almost any possible combination of forces will have had time to act to form mountains. It is estimated that 60 million years have been required to

erode the huge folds which originally made up the Appalachian Mountains.

Are mountains permanent? A mountain is but one stage in the continuous process of change in level of the surface of the earth. Elevation forms the mountain, weathering and erosion break down the materials of which it is made, and finally it is leveled. At any time during the cycle, new forces may elevate the land, beginning the series of changes over again.

——Things to think about——

Match the following subjects and predicates. Do not write in this book.

Subjects

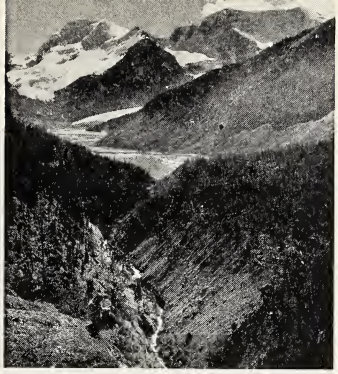
1. Melted rock
2. Volcanic peaks
3. Faulted mountains
4. Volcanic craters
5. Folded mountains
6. Releasing pressure on hot rock
7. The end of all mountains
8. The Appalachian Mountains
9. The Wasatch Mountains

Predicates

A. may permit the rock to become melted.
B. may be formed by the sidewise pressure of near-by rock layers.
C. may exert sufficient force to cause folding of surface rocks.
D. are examples of faulted or block mountains.
E. may have gradual slopes on one side and steep cliffs on the other.
F. are generally more or less cone shaped.
G. are examples of folded and eroded mountains.
H. is reduction to a plain by erosion.
I. may be filled with bubbling, melted rock.

4. What forces level the earth's surface?

You already know that erosion is the chief force which reduces the height of mountains. You know, too, that rocks are weathered, and that the particles loosened by weathering are carried to lower levels of the land or to the ocean. This work of erosion is largely accomplished by running water.



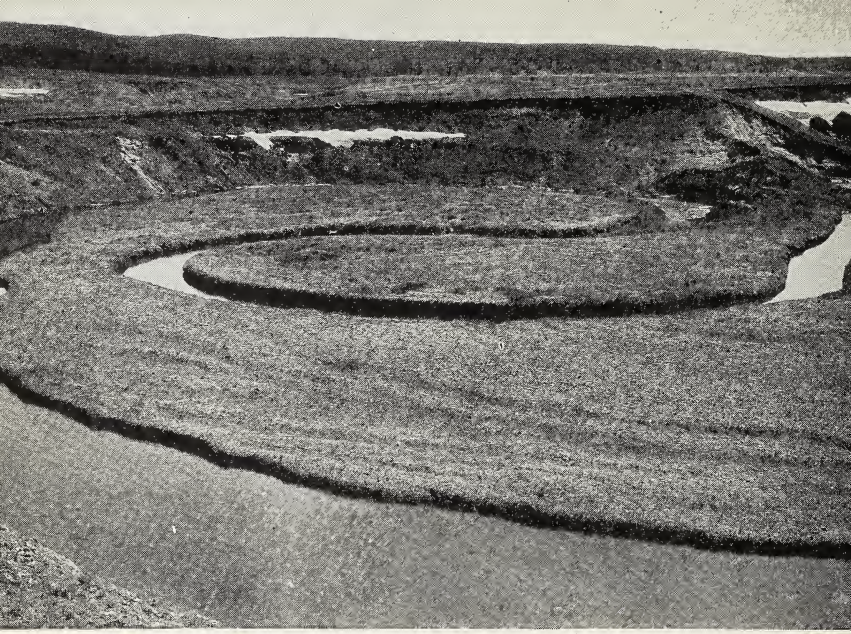
W. J. Gibbon photo.

When a river starts wearing away the land, it cuts itself a steep-sided canyon. Then, as the banks are worn down, the valley becomes V-shaped. This is the Athabaska Valley, Canadian Rockies.

Why are there streams of running water? On every part of the earth's surface some rain or snow falls. In the driest place in the United States, Death Valley, there are about two inches of rainfall per year, while in the wettest regions the rainfall may exceed 200 inches. Some water that falls may lie on the ground as ice or snow, some may evaporate into the air, and some may soak into the ground. A large part of the water runs immediately from the surface on which it falls and forms small streams. The force which moves water downhill is gravity.

Since no part of the earth's surface is entirely level and smooth, running water encounters little difficulty in starting its journey to the ocean. The moving water, which is called runoff, may first flow as a thin sheet, if the ground is fairly smooth and level; or it may immediately find its way to a tiny, trickling stream. The small streams eventually unite to form creeks or brooks which, in turn, combine to form rivers. In many regions rivers combine to form the huge river systems, such as those of the Saskatchewan-Nelson, the Peace-MacKenzie, and the St. Lawrence.

What is the lifework of a river? The lifework of a river is to drain and wear away the land over which it flows. When



Courtesy U. S. Department of the Interior

When a river fills its valley it forms a plain. Then it may wander and curve on the plain. If at a later date it cuts its channel deeper, the river may remain in its curved course.

a river begins its work on a region that has not been previously eroded—for example, a recently elevated plain—there are no valleys in which the stream may flow. It must find its way from one low place to a lower one as best it can. As a result, there are many ponds and small lakes and many waterfalls where the water is forced to tumble over shelves and ridges of rock which bar its way to the ocean. The first work of a river is to cut itself a channel in which it can flow. As the river continues its work, the sides of the valley are washed down by smaller streams and sheets of runoff water. The running water carves openings through the ridges of rocks which cause falls to form. As the work of cutting and widening its valley progresses, the stream drains the land more rapidly and completely. Lakes and waterfalls disappear.

Finally the valley becomes so wide that it is almost level. The bottom of the valley has been cut down to a height but a short distance above sea level. The drainage becomes more sluggish as the slope decreases. If there is no further elevation of the land, the valley may eventually become a flat, marshy plain, with a slow-moving river winding its way between banks scarcely higher than the surface of the water.

Do rivers always complete their lifework? It is unlikely that any river will have time to complete its lifework. The surface of the earth is in such constant motion that no large area is likely to remain long enough at one elevation to be completely worn away by one river system. The land near the mouth of the river may be elevated, forcing the river to cut itself a new channel or even to flow backward. The changing slope of the land may cause the river to change its course. The valley may sink into the ocean long before the river has worn the land down to sea level. One river may cut its way into the valley of another, stealing its water and leaving it almost dry.

How does water cause erosion? Water erodes the land in three ways: by the force of its fall, by dissolving the materials with which it comes into contact, and by grinding action (abrasion) when rocks are rubbed against each other. The stream carries away the materials which it loosens from the land.

The force of the river's fall depends upon the steepness of the slope and upon the amount of water in the river. If you have ever turned on a faucet where the water strikes the ground directly, you know that in a short time a hole is washed out. But running water has little ability to loosen solid rock. Most rock carried by streams is first loosened by weathering, which results when ice, air, heat and cold, plants and animals, and other forces break and crumble the rocks. It is where a loose soil has been formed that rivers can erode the land most rapidly.

Where there is an abundance of loose material to be carried by a river, it may pick up an enormous load. A stream

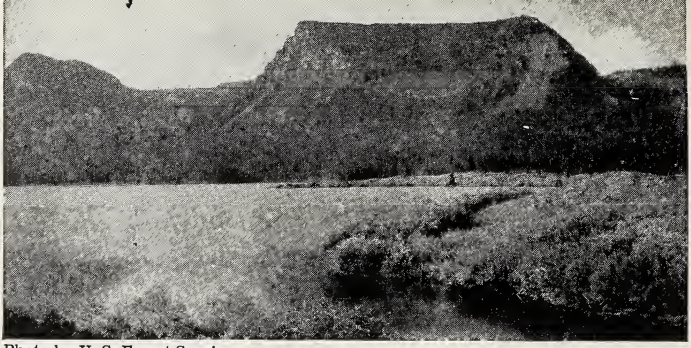


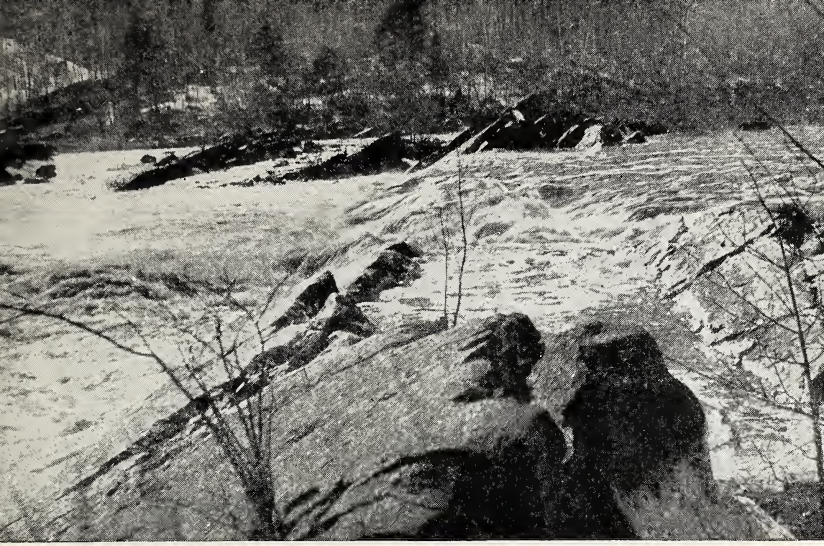
Photo by U. S. Forest Service

Some mountains are formed by surrounding materials being eroded away, leaving huge ridges of stone. A layer of hard rock may protect the ridge from erosion from above while it crumbles along the edge.

flowing at a speed of one mile per hour may carry mud and roll small pebbles along the bottom. A stream flowing two miles an hour will carry much more mud and may roll pebbles more than an inch in diameter along the bottom. Doubling the speed of water increases its ability to carry materials more than you would expect. If a stream increases in speed from one to two miles an hour, its ability to carry solids increases 64 times. Rapid mountain streams can at flood time move boulders weighing many tons and wash out huge canyons within a few hours.

The movement of dissolved materials is greater than seems possible. Every year the rivers of the earth carry about three billion tons of dissolved materials into the ocean, where it remains to add to the salt and other mineral matter which gives ocean water its bitter taste. Erosion by solution carries away the most valuable plant food in the soil, for plants depend for mineral food upon dissolved chemicals from the soil.

The loose pebbles which roll and bump their way along the stream bottom not only wear each other but also cut into the stones buried in the bottom. The rough pieces of rock become rounded pebbles, and the large stones over which the stream flows become smooth. The particles broken off are carried away by the stream.



Resistant layers of rock slow down the process of erosion and cause the formation of waterfalls. The river is gradually cutting a notch in the tilted layer of rock which dams its progress.

The combined forces of erosion cause the river to enlarge its valley in two ways. The valley constantly becomes deeper, until it finally reaches or approaches sea level. It also becomes wider, as the river carries away materials washed down from the valley sides and as the river carves its way into its banks.

How extensive is the work of river erosion? In any one year the amount of soil and rock eroded from a continent may be only a small fraction of an inch deep. But erosion, continued year after year, levels mountains, destroys farm lands, and changes the weight of materials on various parts of the earth's surface. Erosion indirectly may be one of the causes of earthquakes, which result when the balance of forces acting upon the earth's surface is upset.

It is estimated that the lower third or fourth of the Mississippi Valley is largely built of materials which have been washed from the upper valleys, particularly from the east slope of the Rocky Mountains. Off the shore of every conti-

nent there is a shelf of material built from rock and soil carried into the sea by running water.

——Things to think about——

Complete the following sentences to make true statements. Do not write in this book.

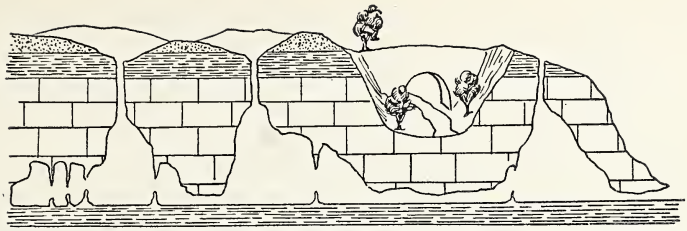
The force which levels the earth's surface is —1— acting to move —2— downhill. The lifework of a river is to —3— and —4— the land. —5— are caused when running water encounters layers of hard rocks through which it cannot cut a channel. Streams move materials which have been loosened by the forces of —6—. Doubling the speed of water increases its ability to carry materials —7— times. When a river has completed its lifework, the land becomes a marshy —8—. The land is —9— drained when a river is beginning its lifework.

——Science activity for fun——

Obtain a garden hose, and sprinkle various surfaces with a gentle spray of water. See if you can observe the formation of a stream. Do you know why waterfalls are formed?

5. How does ground water change the earth's surface?

Only about one-third of the rainfall is carried off by surface streams. The rest either is evaporated or is absorbed by the ground. The amount that soaks into the ground depends upon the type of soil and rock upon which the water falls. If the surface is porous (full of spaces), a high percentage of the water will be absorbed. In certain formations of sand and of limestone, no water may run off at all, but all will sink into the ground. Igneous and metamorphic rocks absorb practically no water. Areas covered with vegetation retain much more water than do areas which are cultivated or which are bare of vegetation.



These formations are typical of a limestone region. Three sinks carry water underground. The cave has three large rooms. Can you see the natural bridge? Where are the stalactites and stalagmites?

Where is ground water found? Some water which soaks into the ground moistens the particles of soil through which it runs. After the particles of soil have taken in all the water they can hold, the rest flows down into the porous rocks until it comes to a layer through which it cannot pass. Such a layer of rock is said to be impervious [ĭm·pûr′vĭ·ŭs, without pores]. Water gradually accumulates in the spaces of the porous rock. If the layer of impervious rock is shaped like a basin, the underground basin holds water somewhat as a lake does. If the impervious layer slopes, the water slowly flows along its surface until it comes to some opening from which it can escape. All such water held beneath the surface of the earth is called ground water.

Ground water is widely distributed, except in deserts. Even in deserts water may be found deep underground, where it has flowed through porous layers of rock from distant mountains. There may be a few regions where the rock is impervious from the surface and all the way down. Water has been found in wells drilled to a depth of two miles below the surface of the earth.

The amount of ground water depends upon the rainfall at the point where the porous rocks appear at the surface. In some places the ground water appears at the surface to form swamps.

Porous rock layers underground may not be continuous. A well drilled on one farm may yield abundant water, while

one drilled near-by may be dry because it enters another type of underground rock layer. There may be breaks in impervious layers where water escapes to lower levels. Dikes and other underground rock formations may interrupt the flow of ground water.

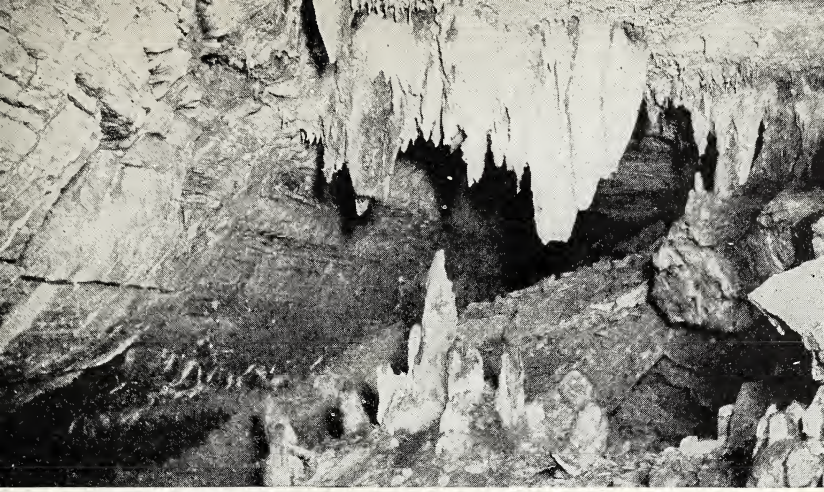
What materials does ground water dissolve? When water flows underground, it dissolves many materials. In limestone regions the rock is easily dissolved, particularly if the water flows from areas on which plants grow. Iron compounds are also easily dissolved in water, and frequently we find reddish-brown stains left by dripping water. Common salt and many other minerals dissolve readily in water.

What formations are made by ground water? In regions where the underground rock is limestone, water dissolves its way into cracks in the rock. The cracks are enlarged until funnel-shaped holes are formed. The surface water drains into these holes, which are called sinks, and either flows away through connecting cracks underground or remains to form small ponds or lakes. The water which flows through underground cracks in the rock usually appears at the surface at some lower level as a spring.

Water flowing through the cracks enlarges them. More water seeps in from connecting cracks, which are in turn enlarged. Thus caves are formed. If the cave is near the surface, the ceiling may fall down, exposing the underground stream to view. If part of the roof of the cave remains, it may form a natural bridge.

There are several natural bridge formations in Canada. One of these is found near Emerald Lake, B.C. Its arch is not very far above the level of the river water. This bridge may have been formed by surface water seeping into a crack across the bed of a stream which was located on a level with the top of the arch. As the water enlarged the crack, the water finally came out through a hole under the present arch. In time the hole became big enough to carry all the water formerly carried by the stream on the surface.

There are many magnificent caverns formed by water dis-



Courtesy U. S. Geological Survey

When water dissolves minerals, these minerals are deposited as the water evaporates or changes in some other way. These stalactites above and stalagmites below are commonly found in limestone caves.

solving limestone rock. Two of the best known are Mammoth Cave of Kentucky and the Carlsbad Caverns of New Mexico.

In Yellowstone National Park the ground water has made many strange terraces and mounds composed of materials brought by hot water from underground.

Why does ground water deposit materials? There are several reasons why water may deposit materials which it has dissolved. If the water was hot when the materials were dissolved, and then cooled, some of the material will be deposited. Cold water holds less of most dissolved materials than does hot water. If water contains carbon dioxide when the materials are dissolved, and the carbon dioxide escapes, some materials will be deposited. The water may dissolve two kinds of chemicals which act on each other to form new chemicals which will not dissolve. Tiny plants and animals may take materials from the water and deposit them. Part of the water may evaporate, causing materials to be deposited.

What materials are deposited by water? Almost everyone is familiar with the beautiful columns of rocks deposited in

Brown photo

This open pit iron mine is just a big hole. The iron which is so near the surface was probably concentrated by water.

caves by water dripping from the cavern roofs. The water dripping from above forms long, icicle-like stone formations. At the bottom, the dripping water forms a cone-shaped mass of rock. The two may eventually join to form a complete column. The formations which resemble icicles are called stalactites [stȧ·lăk′tīt]; those which are formed on the ground are called stalagmites [stȧ·lăg′mīt].

Agates, attractive banded stones collected by many people, are deposited from water. The materials which make up these rocks are frequently deposited in layers inside cavities in other rocks. Each layer of material contains slightly different minerals from the one before, making the banded appearance.

The deposits of rock in Yellowstone National Park are only slightly less famous than the hot springs and geysers which bring the water that leaves the deposits behind.

The most important deposits formed underground are the minerals containing silver, lead, zinc, and other valuable metals. Most of these metals are found combined with other elements in compounds that dissolve readily, especially in hot

water. At considerable depths in the earth the temperature of the water may approach 1000 degrees F. Water so hot dissolves its way through rocks, taking from them the minerals, and finds its way into some convenient crack. There the water is forced by the pressure of the rocks to flow upward. As it flows upward, it cools and deposits its load of minerals in cracks. Such a crack in a rock filled with a mineral is called a vein. The underground water does two extremely valuable things in forming mineral deposits. First, it dissolves from the rocks the scattered minerals, and concentrates [increases in strength] them. Second, it brings these minerals nearer the surface of the earth where we can find them.

DEMONSTRATION. HOW DOES WATER DISSOLVE MINERALS FROM THE SOIL?

What to use: Soil, watch glass, beaker, ring stand, burner.

What to do: Stir the soil in a small amount of water, and let the water become clean either by settling or by filtering it. Put three drops of water on the watch glass, and set it over the beaker, one-third full of water. Put the beaker on the ring stand and boil the water until the water in the watch glass evaporates. Dry the bottom of the watch glass, and examine it carefully. Similarly test tap water.

What was observed: What did you observe on the watch glass? Where does mineral come from? Where does the salt of the ocean come from?

What was learned: Does water dissolve enough material from soil to reduce it in value? Explain.

——Things to think about——

Select the correct word or words needed to complete each of the following sentences. Do not write in this book.

1. Ground water (*a*) wets soil particles (*b*) is held in porous rocks (*c*) runs off the surface (*d*) evaporates.

2. Ground water never (*a*) dissolves materials (*b*) deposits materials (*c*) is hot (*d*) dissolves granite readily.

3. Impervious rocks (*a*) prevent ground water from passing through (*b*) absorb ground water (*c*) are readily dissolved.

4. Caves are formed by the action of ground water on (*a*) granite (*b*) carbon dioxide (*c*) limestone (*d*) soil minerals.

5. Minerals are deposited from ground water because (*a*) they are heavy (*b*) the water may be cooled (*c*) the water boils.

6. Reddish-brown stains left by water indicate the presence of (*a*) agate (*b*) lime (*c*) iron.

7. Mineral veins are formed when (*a*) hot water dissolves minerals underground (*b*) minerals fill caves (*c*) water cools in cracks (*d*) geysers bring water to the surface.

8. Porous rocks are (*a*) granite (*b*) obsidian (*c*) basalt (*d*) limestone (*e*) sandstone.

6. What forces formed the lakes, swamps, plains, and plateaus?

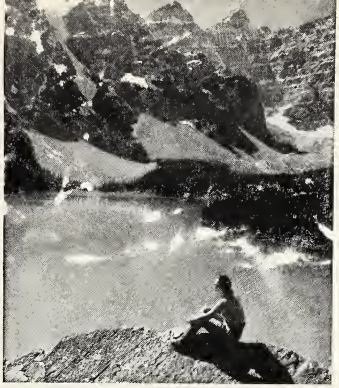
Although volcanoes are more spectacular, and mighty rivers more impressive, it is the flat places of the earth's surface which are most important to us as places to live and as sources of wealth. Almost all agriculture is carried on where plains provide fertile soil. The lakes and swamps are the regulators of the water supply. The plateaus provide agricultural and grazing lands. The formation of these regions is an interesting story.

How were lakes formed? Lakes are formed in two ways: Low places in the earth's surface may be filled with water or some obstruction may block a stream to cause formation of a lake.

Many lakes are found in the depressions scooped out by the huge glacier which about 25,000 years ago covered the

northern United States. As the ice melted, the resulting water filled the low places. Glaciers on mountains may scoop deep holes in the rock, which fill when the glacier is melted.

There are low places in deserts where there has never been sufficient water to form a drainage system. When an occasional rain falls, temporary lakes fill these low places, only to disappear as the water evaporates.



Courtesy C.P.R.

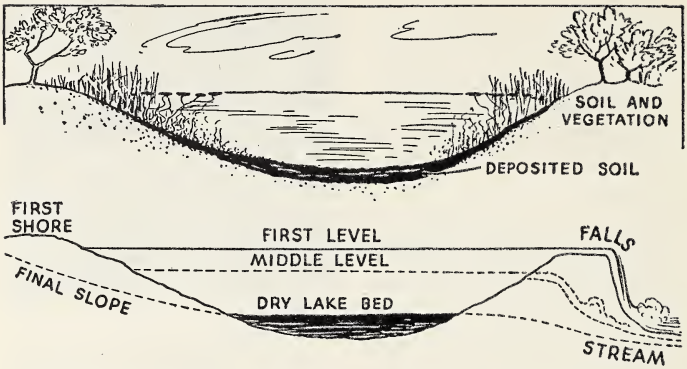
The beautiful mountains and lakes may seem everlasting but they will eventually disappear to be replaced by other mountains and lakes elsewhere. This is Moraine Lake in the Canadian Rockies.

Streams have been dammed in the past by glaciers blocking their channels, either by forcing a dam of earth across the valley or by the ice itself blocking the channel. There are many of these lakes formed behind glacier-built dams in the mountainous regions.

Among the most ambitious of all pond builders are the beavers which build dams across streams to provide themselves with the environment they need for a home. Beavers cut trees for the framework of the dam, use branches and twigs to fill in smaller openings, and cover the whole structure with earth and mud. Beaver ponds are usually fairly small, but they are of great importance in regulating flow of water and in providing still places in rivers.

Why must lakes disappear? Lakes disappear either because they are filled up or because they are drained. Filling of lakes occurs wherever sediment-bearing streams flow into them. At the mouth of the stream a delta may form which gradually builds its way into the lake. Lake Geneva in Switzerland, originally 47 miles long, has been decreased in length seven miles by this filling process.

Vegetation grows out from the shores when lakes become sufficiently shallow. Plant growth can completely cover a



Some lakes disappear because they are filled in by soil and vegetation. Others disappear because the streams which drain them wear their channels deeper until all the water escapes.

lake. In Minnesota a railroad was built across a bog which had been used for grazing land for many years. The surveyors did not discover what the engineers quickly learned—that is, that the apparently solid ground was a mass of vegetable matter and dust four feet thick, floating on about 20 feet of water. Such bogs may be so thin that people may fall through and lose their lives in the oozy water beneath.

As rivers that flow out of lakes cut their channels deeper, lakes are drained. If there is no natural outlet, the overflow from the lake during high water will start one. Once started, each successive period of high water enlarges the channel until the stream flows continually and the lake is drained. A lake formed by a glacier blocking a valley is drained when the ice melts.

How are swamps formed? In a swamp the water table is at the surface of the ground. There may be small areas of open water in swamps, but usually the surface consists of soil and vegetation.

Swamps result when a lake is filled, but before all the water has been displaced with soil or rock. Swamps also occur along the margins of lakes and rivers, where marsh

plants stop the action of waves and currents, permitting soil to be deposited. Most shallow lakes have at least a small margin of swampy land.

There are huge swamps in the valleys of old rivers. When the valley has been worn so flat that there is little slope, the soil becomes completely saturated with water over large areas. The river winds its way over the flat land, frequently cutting itself a new channel. The old channel often remains as a lake, surrounded by swampy land. These river-formed lakes often resemble an oxbow in shape. They are cut off from the main channel of the river by ridges of material deposited by the sluggish river along its banks. Such lakes are found along the lower Mississippi River.

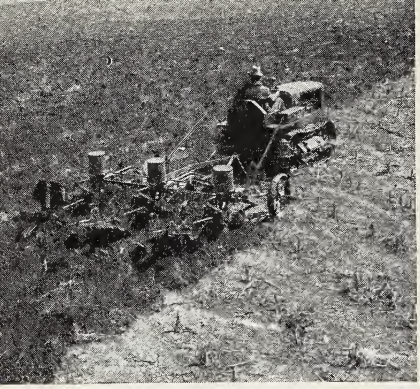
Paul's Photos

The lakes along the lower Mississippi frequently blend into swamps along their shores. The moss-draped oaks grow down to the water's edge. Vegetation gradually fills in the swamp.

There are also salt-water swamps along the ocean, which build soil in the same way that lake swamps do. The plants that grow in salt water, however, are quite different from those which grow in fresh water. After deposits in coastal swamps have changed to stone, it is possible to identify the stone from traces of plant material in it. Thus the edges of ancient seas have been located by study of rocks.

Some swamps contain one kind of bacteria which prevent the growth of other bacteria which cause decay. Plants and animals trapped in swamps are sometimes preserved in amazingly fine condition. In the Red Deer Valley, one such swamp trapped many huge dinosaurs. The remains of many prehistoric animals have been found in this Alberta area.

How are plains formed? Any region that is fairly flat and has only scattered hills is called a plain. The land may be



Courtesy Caterpillar Tractor Co.

This level farm is part of the Great Plains. Much of the soil composing these plains was washed down from the Rockies.

gently rolling or may slope slightly. Plains are usually found at low altitudes. They may be formed by elevation of the ocean bottom or built up of sediment deposited from water. Some plains are formed by the filling, draining, or drying up of swamps and lakes.

Some plains are formed by erosion of the land. The original, fairly level, surface of land is worn down as a river completes its lifework—first into series of ridges; then later into rolling hills and flat valleys. Eventually the surface may become level again.

Coastal plains are built up by materials washed from steep mountain slopes to the comparatively level ground along the shore. As the rushing water slows its speed, the materials it carries are deposited along the coast, forming a narrow plain.

What level areas are found at high altitudes? A plain which occurs at a high altitude is called a plateau. In some plateaus the rock has been elevated directly from the sea bottom, and the layers are still level. The Colorado Plateau, through which the Colorado River has cut the Grand Canyon, has nearly level layers. In other plateaus the rock layers may be tilted sharply, with the rocks lying at an angle. The plateaus of the Appalachian region were formed by wearing down of the folded rocks of which that part of the country is composed.

Sometimes it is difficult to distinguish between plains and plateaus. The Piedmont Plateau, along the eastern side of the Appalachian Mountains, is actually lower than the central plains of the Mississippi Valley. The Piedmont Plateau is higher than the coastal plains.

Plateaus are worn down by erosion. In fact, it is on plateaus that rivers ordinarily begin their lifework. Many plateaus are deeply cut by the canyons of rivers. Examples of this cutting may be found in the valleys of the Snake and Columbia rivers in the West. On other plateaus the river has not begun its cutting action, and it flows on top of the plateau. At the edge of such a plateau there is likely to be a series of rapids or waterfalls. There is such a fall line along the edge of the Piedmont Plateau.

Where plateaus have been eroded away to some extent, interesting formations of rock may be left standing. These often take the form of a flat-topped hill called a mesa [mā′ sȧ] or a butte [būt]. The top of a mesa is usually larger than that of a butte. In other regions erosion has progressed until remaining formations are hills or mountains.

——Things to think about——

Complete the following sentences. Do not write in this book.

Lakes are formed where —1— in the earth's surface fill with water or where a —2— is blocked by an obstruction. Lakes are filled by —3— from rivers or —4— as rivers complete their lifework. In a swamp the —5— is at the surface of the ground. An oxbow lake is formed in an abandoned river —6—. —7— plains are formed from materials washed from steep mountains to the border of the sea. An elevated level surface is called a —8—. A large, flat-topped hill left by erosion of a plateau is called a —9—.

7. How have the oceans affected land surfaces?

No matter how far you live from the ocean, it is an important part of your environment. It not only is a major factor in causing weather changes, which constantly change the earth's surface, but it also is an important factor in building

Upon rocks worn smooth by the action of waves live seaweed of various kinds. In the seaweed live the starfish, anemonies, and crabs. Was this picture taken at high or low tide?

the rocks and the land. The ocean is the storehouse for most of the water of the earth.

How does ocean water move? Everyone who has seen the ocean, or a good picture of the ocean, is likely to think first of the waves breaking on beaches or beating against rockbound coasts. Yet the motion of waves makes up only one of the four movements of ocean water. The second motion of the water of the ocean is the drifting surface water which forms currents. Some of these currents are of great extent, covering half the ocean. There are five main drifts or currents in the world, one each in the North and South Atlantic, one each in the North and South Pacific, and a huge drift in the Indian Ocean. The winds which move the water in these drifts drive the water against the continents, which turn them aside to

make huge, circular movements. The third movement of the ocean is the tides, which regularly cause the water to rise and ebb every 12 hours and 51 minutes. The fourth motion is a very slow current of cold water along the bottom of the ocean from the poles to the equator, and an opposite slow current of warm water to polar regions from the equator. This motion is similar to the movement of water in a heating tank.

In addition to these great movements of ocean water, there are other and smaller movements. A river running into the ocean sets up a current which may be traced for miles by the freshness of the water and by the sediment which it carries. There are small currents set up by waves and the wind.

What is the bottom of the ocean like? When the earth was first formed, its surface was made up entirely of igneous rocks. Because granite is lighter in weight than basalt, the granite rocks were forced upward to form the mountains, and the heavier basalt rocks sank to form the bottoms of huge depressions. As the earth cooled, water condensed from its atmosphere and flowed into the depressions to form the oceans. The basalt rocks which originally formed the ocean bottom have been covered by deposits of material washed from the land and by materials settling from the ocean waters.

Knowledge of materials and the shape of the ocean bottom is obtained by scientists who use boats for their laboratories. One device used sends sound waves to the bottom of the ocean, from which they are reflected to form echoes. An electrical listening device catches the echo, and makes a record of the time between the original sound and the echo. The depth of the ocean can be figured from the time it takes for the sound waves to travel to the bottom and back.

There are deeps in the ocean—more than 50 in all are known—where the bottom is much lower than that of the average. The greatest depth occurs just east of the Philippine Islands, where measurements show that the water is nearly seven miles deep. There are also ridges which correspond

Courtesy Mildred Vihstadt

Waves sometimes cut rocky shores into rugged cliffs. Where the water is fairly deep, large rocks along the shore are more common than fine particles of sand.

to mountain ranges on land. Some of these ridges extend above the surface to form islands.

The bottom of the ocean is generally more regular than the surface of the land, because there is no erosion there. There are differences in height, however. Near the continents the bottom of the ocean forms a shelf, which varies greatly in width. Along the Atlantic Coast it is as much as 60 to 80 miles wide, while along the steeper Pacific Coast it is less than 10 miles wide. These shelves are broadened as materials are deposited from water flowing from the land.

Samples of the ocean bottom are taken by shooting a tube into it with an explosive charge. The tube containing material from the ocean bottom is drawn to the top.

How are the rock materials deposited? The continental shelves are made up largely of the coarser materials carried into the ocean by rivers. If the water is comparatively shallow and free from currents, the rivers may build deltas, parts of which appear as land and parts of which cover the ocean bottom. A delta takes its name from a triangular Greek letter Δ.

Finer sediments may be carried beyond the continental shelves where they slowly settle to form fine-grained sedimentary rocks. The bottom of the ocean beyond the continental slopes is composed chiefly of materials carried by the wind and deposited on the water as dust, together with the skeletons of tiny, floating animals. These deposits are called ooze.

How do waves change the shore line? Where the land

is being raised, the shore line is rocky and steep. Here the waves pound against cliffs. The water alone has little effect in cutting the rock, but it picks up sand and pebbles which it hurls against the cliffs. In this way the shore is undermined until the rocks break along their joints and tumble into the ocean. Caves may be formed if the rock is quite solid. Sometimes the roof of a sea cave may collapse, leaving an arch much like a natural bridge.

Courtesy Daytona Beach Chamber of Commerce

A broad, sandy beach is a wonderful playground. Waves roll in and break as they meet the sloping land. Why is swimming in the surf dangerous?

The waves wear away only the rock above the water line. That below the water line is left as a bench. In time the rock materials collect on this bench to form a beach. Hard rock wears slowly, and the eroded material usually forms a gravel beach. Softer rocks wear more rapidly, and the material left forms a sandy beach.

The water carried onto the beach by breakers returns to the ocean as an undertow. This current carries the finer eroded materials out from the shore to be deposited in quieter water. After many years this material may accumulate to form a bar. Many harbors have bars across their mouths, making navigation difficult. It may be necessary to build walls to stop wearing of the beach or to dredge the harbor entrance to keep the harbor open. Sometimes if walls are built to make the channel narrower, the current speeds up enough to carry the fine materials farther to sea.

In the quiet water behind the bar, materials deposit more

Courtesy Arta Verity

Sand dunes along the seacoast often are covered with vegetation, because quick-growing plants take root in the moist sand. The plants slow down the blowing sand so that such mounds of sand stay in one place for some time.

rapidly than in the open ocean. The accumulated sediments build marshy land which eventually becomes part of the coastal plain.

The bars may grow far into the ocean if the direction of the wave motion is favorable. Sandy Hook, which extends out many miles into lower New York Bay, was formed by ocean currents caused by waves.

Why are there different types of shore lines? Compare the east and west coast lines on a map of the United States. You will see that the West Coast is quite regular, while the East Coast is irregular and fringed with islands, bars, and deep bays. The West Coast is generally rising, except in the region of Puget Sound. On the West Coast such shore formations as benches, beaches, and sea caves are found high above the present water level. On the East Coast there are many remnants of land formations rising above the water. River valleys extend out to sea on the ocean bottom.

Along the southern Atlantic Coast and along the Gulf of Mexico the shores are low, and the coast is dotted with many sandy islands back of which are found the stretches of still water called lagoons. The land along the Gulf is low, and the water near shore is shallow. There is little erosion because of the lack of slope, and the action of waves attacks the shore line to form wide beaches.

Shore lines and beaches are left behind as the land rises, and provide one of the most important means of identifying

the changes which have taken place in the earth's surface. The study of shore formations, rocks, and fossils shows that the whole interior of the continent now occupied by the Mississippi Valley and extending into Canada has been at times beneath the waters of the ocean.

——Things to think about——

Complete the following sentences. Do not write in this book.

The water of the ocean moves up and down in —1—, rises and falls in —2—, and circulates in huge surface —3—. The ocean bottom is probably —4— rock. Above the water line of a wave-cut shore are found —5—, and below the water are found —6—. Materials eroded from rocks by waves may form —7— or —8—. River deposits extending into the ocean as solid land are called —9—.

A Review of the Unit

Because gravity causes the various regions of the earth's surface to come to a balance, many changes in the level of the surface occur as materials are eroded from one surface and deposited on another. The runoff and ground water are the principal agents of erosion, which tend to reduce elevated areas to plains at lower levels. The work of erosion and the movements of ocean water are produced by the force of gravity and the energy of the sun. Proof that there have been many surface changes is found in the composition and position of the rocks, and in the various formations which make up the different types of landscapes.

An exercise in thinking

Match the principles and related ideas, according to directions given in the review at the end of Unit 1.

List of Principles

A. Constant changes in pressure of the rocks cause the surface of the earth to be raised and lowered.

B. The lifework of a river is to drain and wear away the land.

C. Ground water does its work of erosion by dissolving minerals.

D. When changes occur in water containing dissolved materials, the materials may be deposited.

E. Igneous rocks are formed by cooling from the melted state.

F. Sedimentary rocks are composed of materials deposited from water or wind.

G. Metamorphic rocks are changed in form by heat, pressure, or water.

H. The erosive action of waves depends upon use of rock materials for cutting tools.

List of related ideas

1. Limestone is soluble in water containing carbon dioxide.
2. A river valley increases in length by cutting the channel back toward the source.
3. Many iron ores have been separated from the rocks by water.
4. Many mountains are formed by erosion by running water.
5. Earthquakes occur at times along the Pacific Coast.
6. Limestone is formed from the shells and skeletons of sea animals.
7. Presence of limestone rock on the surface is proof that the land has been raised.
8. The Appalachian Mountains were formed by folding of rocks.
9. The first valleys formed by a river are V-shaped.
10. Dikes are found separating layers of rocks of other types.

11. Many mountains were once active volcanoes.

12. Limestone caves are always formed by solution.

13. Limestone changes to marble when enough heat and pressure are exerted on it.

14. Rocks are worn slowly along the shore where the water is deep.

15. Minerals occur in veins in which water has cooled.

16. Conglomerate is a rock composed of cemented pebbles.

17. Sea caves are formed by undermining solid rocks.

18. The terraces of Yellowstone National Park are built by hot water.

19. Slate may get its black color from vegetation present in the clay materials from which it was formed.

20. Much of the fertility of the soil is lost to the ocean.

21. Deposits of sand along the continental shelf form coarse rocks.

22. Beaches occur where a bench has previously been formed.

23. In many places there is little surface drainage because the water flows into sinks.

24. The first rocks forming the bottom of the ocean were basalt.

25. Limestone columns are found in most caves.

26. The Hudson Valley extends beneath the water on the ocean bottom.

27. When lava flows beneath rocks and heats them, they often change in form.

28. The size of the crystal in some rocks is an indication of the rate of cooling.

29. Pebbles along the beach are always rounded.

30. The fine-grained rocks of the ocean bottom are composed of shells of tiny animals and dust carried by the wind.

31. Beaches are sometimes found on high mountains.

32. Zinc, gold, and silver are taken from veins formed in cracks in the rocks.

33. A layer of sedimentary rock that is found at the surface in one region may be buried far beneath the surface in another place.

34. Lakes tend to disappear as the level of the land is lowered by erosion.

An exercise to test yourself

Select the correct word or words needed to complete each of the following sentences. Do not write in this book.

1. The limestone which is removed to form caves is (*a*) worn away (*b*) washed away (*c*) dissolved.
2. The existence of rocks containing shells and skeletons of sea animals at high levels shows that (*a*) the land has been elevated (*b*) the water has gone down (*c*) these animals were once capable of living on land.
3. Sideways movement of rock is invariably accompanied by (*a*) a landslide (*b*) breaking of the rock (*c*) outpouring of molten rock.
4. Rocks composed of fine particles in uniform layers are (*a*) conglomerates (*b*) sedimentary (*c*) igneous.
5. Materials deposited at the mouths of rivers may form (*a*) elevated ridges (*b*) hooks (*c*) deltas.
6. The principal materials deposited on the bottom at mid-ocean are (*a*) sand loosened by wave action (*b*) dust carried by the wind (*c*) sediments carried by rivers from high land regions.
7. Sand beaches are formed by erosion of (*a*) sedimentary rocks (*b*) metamorphic rocks (*c*) igneous rocks.
8. A shore line fringed with many lagoons, bars, and bays is (*a*) in the process of formation (*b*) rising (*c*) already well eroded.
9. Regular shore lines are commonly connected with a seacoast that is (*a*) rising (*b*) sinking (*c*) already well eroded.

Some things to explain

1. Try to discover how the region in which you live has been changed by the forces you studied in this unit.

2. Why are there so many kinds of rocks?

3. Why is a creek bed a better place than a plowed field to hunt for rock specimens?

4. Why are there no caves in regions composed of granite rock?

5. Why do farmers living on hills have a more difficult time to keep the soil fertile than do those living in valleys?

Some good books to read

Berry, Pauline, *Stuff*
Compton's Pictured Encyclopedia
Fairbanks, H. W., *Stories of Rocks and Minerals*
Fenton, C. L., *Our Amazing Earth*
Fenton, C. L. and M. A., *The Rock Book*
Fletcher, Gustav L., *Earth Science*
Fraser, C. C., *The Secrets of the Earth*
Heal, Edith, *The Story of Geology*
Hotchkiss, W. D., *The Story of a Billion Years*
Lee, Willis T., *Stories in Stone*
Mather, Kirkley F., *Old Mother Earth*
Reed, W. M., *The Earth for Sam*
Washburne, H. and Reed, F., *The Story of the Earth and Sky*
World Book Encyclopedia

Courtesy International Harvester.

UNIT FIVE

HOW DO WE OBTAIN HELP WITH OUR WORK?

Do you find it easier to climb a ladder or to run upstairs? Do you prefer to use an ax to break wood for a fire, or is it easier to break it with your hands? Do you refuse a ride to school in order to have the privilege of walking? Do you eat soup with a spoon, or do you eat it without any silverware?

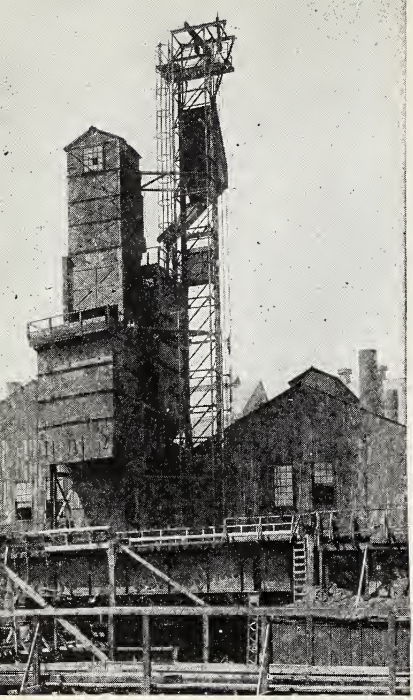
If you choose the stairs, the ax, the automobile, and the spoon, then you are using machines to get help with your work. For it is true that all the acts mentioned are work, even if you ordinarily do not think of them in that way. Work is merely the process of causing something to move, whether it is for fun or to get something done that is unpleasant.

Anything that helps you to apply force for the purpose of moving something, whether it be a spoonful of soup or a ton of coal, is a machine. We are so accustomed to thinking of machines as being big and impressive that we are likely to forget the little, everyday machines that make life much easier for us.

By use of machines we cannot save work, but we can make it easier for ourselves. It takes the same amount of work to run upstairs that is required to climb a ladder to the same height, but we do not make ourselves so tired by use of the stairs. We say that the stairs are easier to use, because the climb is more gradual. That is exactly what a scientist would say, too, but he would express it more accurately.

Although it is impossible to do work without using energy, it is not necessary for us to use our own energy to do it. We can use many other forms of energy instead. It is easier to push the button and let the electric current turn the washing machine than it is to put a crank on it and turn it by hand. It is easier to step into the elevator than it is to climb stairs.

We are so accustomed to using machines that we could hardly live without them. Our food, water, transportation, and clothing are made available to us only because we have machines to use. In fact, the age in which we live is called a machine civilization. Can you think of a better name for it?



Courtesy Minneapolis Gas Light Company

The hoist tower is a familiar device for doing work. A car loaded with coal is lifted by cables to the top of the tower. The coal is used in the manufacture of city gas.

1. What is work?

Doing work has already been defined as causing something to move. True enough, but you know that things do not move easily. There is always something that holds them back — a resistance to motion. What this resistance is depends upon the situation. If it is opening a drawer that is stuck, it is one kind of resistance. If it is lifting a box of canned corn, it is another. And if it is pushing an automobile on a level road, it is still a third kind of resistance.

How does gravity offer resistance to doing work? Everything on the earth is pulled down toward the earth's center by the force of gravity. If you want to lift any object, you must pull up with more force than the downward pull of gravity. Lifting anything is really a tug of war with an invisible opponent.

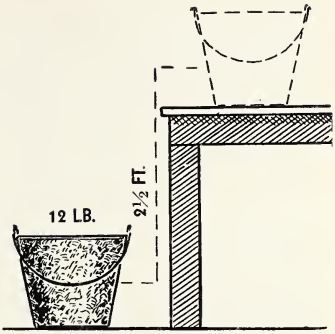
The energy you apply to lift an object is called a force. A force is a push or a pull.

If you do not push or pull on an object with enough energy to cause it to move, you are not doing work. You might stand and lift at the corner of the school building all day, and at night be completely tired out. But, unless something very unusual happened, your efforts would go to waste without having accomplished any work. Yet if you blink your eye, you have done work; for even so slight a movement as that

of an eyelid is use of energy to move something.

The scientist says that work is done when force overcomes a resistance. The way to measure work is to find the amount of force used, and to find how far the object was moved by the force.

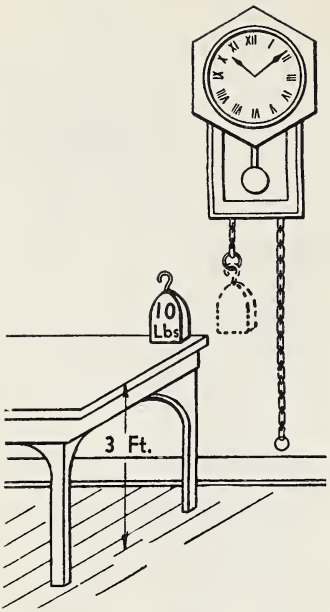
Suppose you start with a pail of water on the floor. The pail of water weighs 12 pounds, and the table is 2½ feet high. You want the pail on the table, so you lift it. How much work have you done? Easy. Twelve times 2½ equals 30. But 30 *what?* The distance is in feet, the weight in pounds. The name of the unit of doing work, then, is the *foot-pound.*



Explain how 30 foot-pounds of work is done when the pail is lifted to the table.

Then you have a faucet on the bottom of the pail, and a toy water wheel which you are using to operate a mechanical toy. You run a hose from the pail to the water wheel, and the water turns the wheel around at a great speed. Where does the energy come from? You can easily see that the energy which you stored in the water by lifting it is being released when the water runs downhill and turns the water wheel.

There is a big machine called a pile driver which works on the same principle. It is made of posts and pulleys and other parts. An engine pulls a weight up to the top of the posts. Then it is turned loose, and it crashes down on the top of a post which it drives into the ground. This machine is used to drive the posts you may have seen around the ends of docks. The machine does work in using energy to lift the weight. Then the same energy is used to drive the post. Of course there is some loss of energy because the parts of the machine rub against each other.

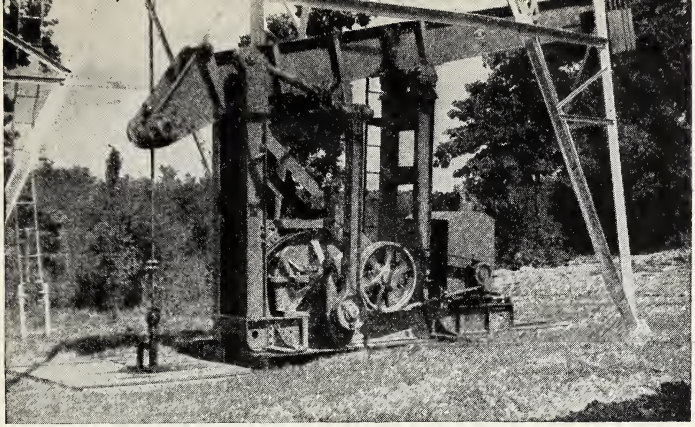


The weight on the table contains stored energy. This energy may be released to do useful work by hanging the weight on the chain of the old-fashioned clock. How much work can be done?

Just how much is a pound? A pound is the amount of pull which gravity exerts upon a standard measure. This measure is a piece of metal kept in the Bureau of Standards in Washington, D. C. It is carefully protected to keep it from gaining weight by rusting or by dirt sticking to it or from losing weight by being worn away or scratched. Any other piece of metal with the same amount of matter in it as this standard weight is a pound.

The easier way to measure a pound is to use an ordinary spring balance. Gravity acting on a weight can be used to stretch the spring. All weights which are equal will pull the spring down equally far. And if we do not have too strong a spring or too heavy weights, two equal weights will pull the spring down twice as far as one of them will. It is thus easy to make a spring balance that will weigh objects. We need only put a pointer on the spring, and note by marking on a scale where the pointer is when one, two, three, or more pounds are added. The one thing we must be careful about is to avoid stretching the spring so much that it will not go back to its first position when we take the weights off.

How can we measure work? It is easy to measure the amount of work done in lifting an object. You multiply the weight times the distance you lift it. If you want to measure



Courtesy Parkersburg Rig and Reel Co.

This oil well pump does work. It lifts crude oil from a deep well against the force of gravity.

a push or pull sideways, knowing the weight of the object moved is not enough. If you use the spring balance to pull with, you do the work and measure the force at the same time. You can pull a wagon along the sidewalk with a spring balance, noting the pull. Then of course you must measure the distance too. Then you can multiply the force by the distance to get the answer.

When you pull a wagon along the sidewalk, you overcome friction, and you also overcome the natural tendency of any object to stand still. If you note the pull on the balance carefully, you will see that the first pull required to start the wagon is greater than that required to keep it moving. When you stop pulling, the wagon does not stop immediately, but has a tendency to keep moving. If you want to stop it suddenly, you must use force. Things resist being started or stopped.

Of what use is work? When we want anything moved we must do work. Getting wood for the fire or going to bed is work. These common activities are familiar to all.

In factories there is much work to do. After a locomotive has been made, it is necessary to move it to a track. The locomotive is picked up by a system of pulleys operated by

a big engine and carried along a track near the ceiling, until it is put down on a regular railroad track to run under its own power.

To move a hill aside to make a road requires a tremendous amount of work. You probably have watched steam shovels, trucks, and tractors knocking the hill down and hauling it away. In lumber camps logs must be hauled long distances through the woods, put on trains, and taken to the mill. In the mill there are many saws and other machines which cut the logs into boards. Cutting is another kind of work.

On the farm there is a system of pulleys used to lift hay into the barn. A horse does the work by walking along the ground. The pulleys serve as machines to apply the force.

There are so many other uses of work that you can make your own list of hundreds of examples.

Demonstration. How Can We Measure the Force of Gravity?

What to use: Door spring, weights, ring stand, ruler.

What to do: Hang the door spring on the ring stand. From it hang enough weights so that it will almost stretch. Then add more weights, measuring the amount of stretch with the ruler. Repeat the experiment to test your accuracy. If the results of the two trials do not agree, do the experiment a third time.

What was observed: What two forces act upon the weights? Which force pulls upward? Which pulls downward? Is the force of gravity in proportion to the amount of matter in the weights?

What was learned: How can we measure the force of gravity? Explain.

——Things to think about——

Complete the following sentences. Do not write in this book.

One of the forces which must be overcome in doing work is the force of —1—. When work is done, something must be —2— through a —3—. When an 80-lb. boy "chins" himself by lifting his weight 1½ feet, he does 120 —4— of —5—. —6— which is used to do work comes from the sun. The marks on a spring balance represent the pull of —7— on the spring. The standard measure for comparing weights is kept in —8—. A —9— can do more work than the human body. Work cannot be saved but —10— work can be avoided.

——Science activity for fun——

Look up pictures of pile drivers in reference books, and make a model pile driver.

2. How does friction force us to do more work?

All of the energy which we expend does not produce useful work. When we push a box along the floor, most of our energy is used to overcome the resistance caused by the box rubbing against the floor. When an engine pushes an automobile along the road, only part of its energy moves the car. A part of it is used up as the moving parts of the car rub together.

What is friction? Whenever two surfaces rub together, there is a resistance to motion. This resistance is called *friction.* Friction makes it possible for us to walk across a floor. Walking on ice is difficult because there is little friction, and walking with roller skates is still more difficult. There is no movement in the world that does not depend in some way upon friction.

Some friction is desirable; friction makes it possible to sharpen a knife on a grindstone. When the knife is held against the stone, the friction of the stone cuts and scratches the steel until part of the material is worn away. Usually friction is undesirable. Dragging a trunk across a level floor to get it to another place is waste work, for nearly all of the energy is used to overcome friction.

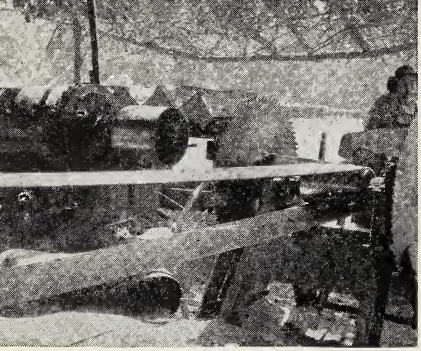


Photo by U. S. Forest Service

Without friction a sawmill would be of little use. The belts would slip upon the pulleys, the teeth of the saws would slide upon the wood. This small sawmill cuts wood for fuel.

What becomes of energy used in overcoming friction? If you drive a nail into a board and quickly pull it out, it feels hot to the touch. The wood does not feel hot because it is a poor conductor, while the nail gives off heat readily. Driving the nail into hard wood makes it hotter than does driving it into soft wood, because more energy is required to overcome the greater friction of the hard wood against the nail.

When an automobile moves, energy is lost as the parts of the machine rub against each other. Although each part seems perfectly smooth, it really is not, and friction results. The energy used in overcoming friction is lost in the form of heat, but since the heat is distributed in many parts, no one part becomes particularly warm. The friction of the wheels against the road produces heat generally not noticed. However, the temperature of the tires may be raised as much as 70 degrees F. by fast driving.

Work used to overcome friction always produces heat. The same amount of work always gives the same amount of heat. Work used in overcoming friction cannot be used over again as can work done in lifting objects. The heat produced is lost into the air, never to be recovered.

How much work is used in overcoming friction? If you use a spring balance to pull a box with a smooth bottom across different surfaces, you can learn a number of things about friction. The forces required will be found to be much different for pulling the box across various rough and polished surfaces. From this experiment you can discover that the amount of friction varies with the kind of surface.

If you change the load in the box by adding weights, you discover that the friction increases. Thus you learn that the amount of friction depends upon the pressure as well as upon the kind of surface. If you place the box on some rollers and measure the force needed to move it, you find that the force needed is still different. Rolling friction cannot be compared directly with the sliding friction because it makes the work much easier. Rolling friction varies with the load and with the amount of surface on which the rollers turn.

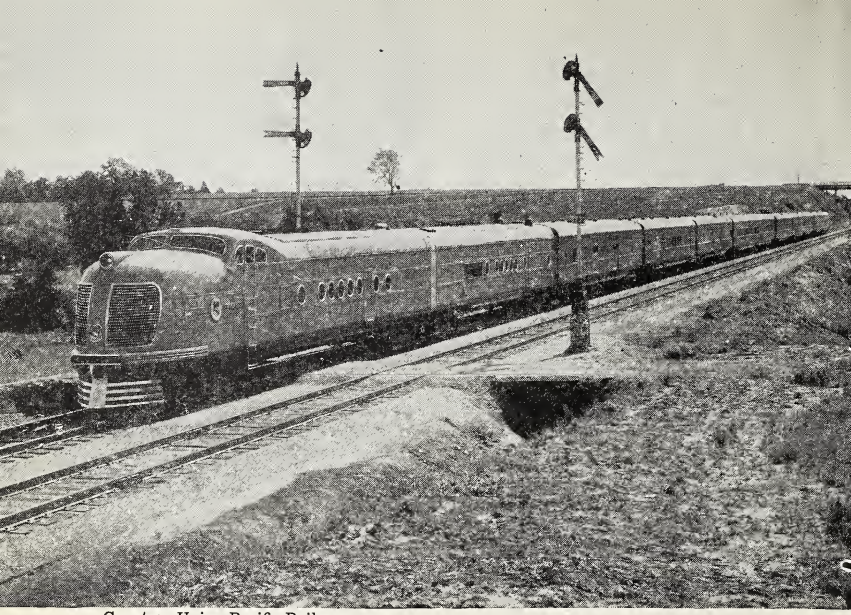
Asahel Curtis photo

Apples unloaded from the truck are pushed on rollers to the inclined elevator. Beneath the boxes on the incline is a belt operated by a motor which lifts the boxes to the second floor.

How can we increase the amount of useful work? From our experiment with the boxes, we find that we can reduce friction by using smooth surfaces. Streamlined trains are made of polished metal, and airplanes are welded so that no rivet heads stick out to increase friction in the air. Axles and wheels are made of highly polished metal.

Because energy is costly, it is important to prevent its loss by friction as much as possible. One of the commonest ways to reduce friction is by the use of oil. Oil forms a thin film which coats the moving surfaces and makes them smoother. Oil is used on the sewing machine, the washing machine, the electric fan motor, and squeaking door hinges to reduce friction. In the automobile, oil is applied wherever two parts rub against each other. If there is too little oil, the parts of the machine may soon become hot and stick. The metal which is rubbed together may even be melted by the heat produced.

Modern transportation depends upon the use of wheels to overcome loss of energy by using rolling friction. The ordi-

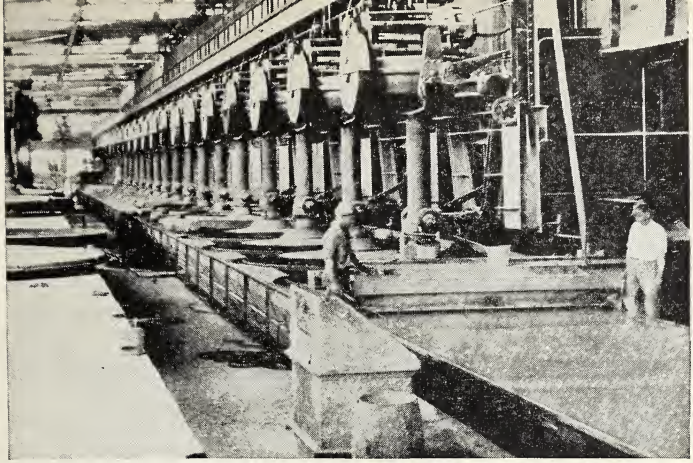


Courtesy Union Pacific Railway

The chief resistance to motion in trains is friction. This train has roller bearings to make the wheels turn more easily and a streamlined shape to reduce friction of the air.

nary wheel is built around a *hub* [center part] which turns upon an axle. The friction between the inside of the hub and axle is a sliding friction. This may be changed to rolling friction by the use of balls or steel rollers. A groove is cut into the inside of the hub and the outside of the axle, and the steel balls are inserted to carry the load. These are called ball bearings. Adding oil to the ball bearings protects them from wear and makes them run still more smoothly.

Roller bearings consist of a row of round rods placed around the axle to roll as the hub turns. These have the advantage over the ball bearings of standing up under much heavier loads. Balls tend to flatten when subjected to too much weight. Nearly all the best passenger trains now use roller bearings to provide smoother riding and greater economy.



Courtesy Pittsburgh Plate Glass Co.

These machines apply friction to make plate glass shiny. The first grinders use sand, the next fine sand, the next emery, and the last rouge on felt to smooth the glass.

Smoothing roughened surfaces also helps to reduce friction. Desk and table drawers which stick and squeak may be made to slide more easily by applying soap to the places where the friction is greatest. If the drawer is too tight, the friction may be caused from pressure. In this case, it is better to plane off a thin shaving of wood to reduce the friction.

A ring may be removed from a finger easily and without pain by soaping the finger thoroughly. The soap makes the surface slippery and permits the ring to slide off easily.

The joints of the bones and all parts of the body which slide upon each other are made smooth by a slippery liquid which reduces friction.

Where is friction useful? Friction helps objects get started. If you have seen automobile wheels spin on wet or icy pavement, you know how hard it is for them to start with friction reduced. Also, without friction, brakes would not hold, and cars would continue to move. Without friction it would be impossible to drive in traffic.

Friction is used for polishing as well as for grinding. Plate

glass is rolled out on a table-like surface, and then polished with grinding wheels until it is smooth and of uniform thickness. Floors are cleaned by sanding machines.

Without friction, the use of belts to carry power from the pulley of one machine to that of another would be impossible. Special types of belts have been developed to lessen their tendency to slip. Even using a lead pencil depends upon friction. Rubbing the pencil against rough paper removes part of the lead.

Friction is both a great helper and a great handicap in doing work.

Demonstration. How Can the Amount of Friction Be Changed?

What to use: Brick, board, round pencils, soap, spring balance, light string.

What to do: Tie the string to the brick so that it can be dragged along the board by pulling it with the spring balance. (1) Note the amount of force needed to pull the brick along the board. (2) Put pencils under the brick to serve as rollers, and pull the brick along. Note the force required. (3) Wet the board, and soap it until it is slippery. Again drag the brick on the board, noting the force needed. (4) Put the brick on the floor, and jerk the string violently.

What was observed: Record the results of the three parts of the experiment.

What was learned: What are two methods of reducing friction? Does an object at rest tend to remain at rest? Explain.

——Things to think about——

Match the following subjects and predicates. Do not write in this book.

Subjects

1. Friction
2. The energy lost by friction
3. Loss of energy by friction
4. Use of oil on surfaces
5. Steel knives
6. Two kinds of friction
7. Steel balls
8. Increasing the pressure
9. Useful friction

Predicates

A. reduces friction.
B. reduce friction in bicycle wheels.
C. is changed to heat.
D. is applied in automobile brakes.
E. is wasted for doing work.
F. will increase the work lost by friction.
G. results when two surfaces rub together.
H. are rolling and sliding friction.
I. may be cut by friction.

——Science activities for fun——

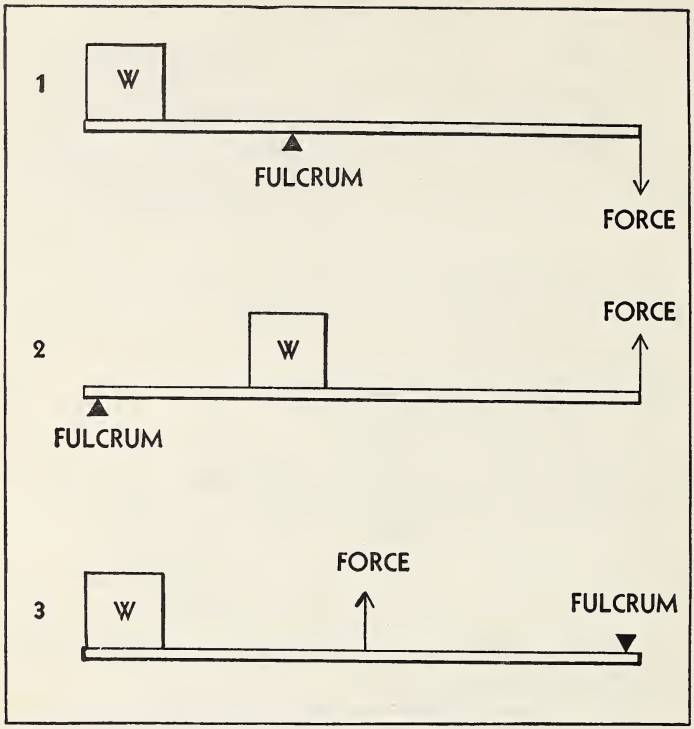
1. Work a demonstration of friction, using a roller skate, a brick, and a spring balance.

2. Rub a penny briskly on your rough clothing. Does it become warmer?

3. How do we use levers to do work?

Without realizing it fully, we are using levers all the time. Knives, forks, spoons, pencils, brooms, shovels, wheelbarrows, and hammers are levers. In addition to their uses in simple tools, levers make up many of the parts of more complex machines, such as the automobile, the washing machine, and the egg beater.

What is a lever? The simplest kind of lever is a stick or bar used to pry or lift some object in order to move it. A *force* is applied to the lever at some point along its length.

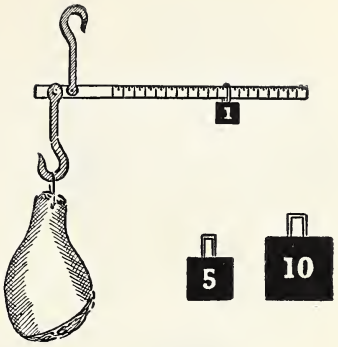


There are three ways that the force, the fulcrum, and the weight or resistance may be arranged. Because of this we say that there are three classes of levers.

The object being moved offers *resistance* at some other point on the lever. The lever rests upon a support or turns around a point, called the *fulcrum.*

Perhaps the simplest form of lever is a teeter board. One child provides the force and the other the resistance. The board rests upon a support placed between the children. As you know, a small child can balance a large child on a teeter. The smaller child must sit farther from the fulcrum than does the heavier child.

The fulcrum need not always be between the force and the resistance. One end of a pry pole rests upon the ground, which serves as a fulcrum. The force is applied by a man lifting upon the opposite end. The resistance, which is usually a heavy stone or timber or pipe, rests upon the lever between the fulcrum and the force.



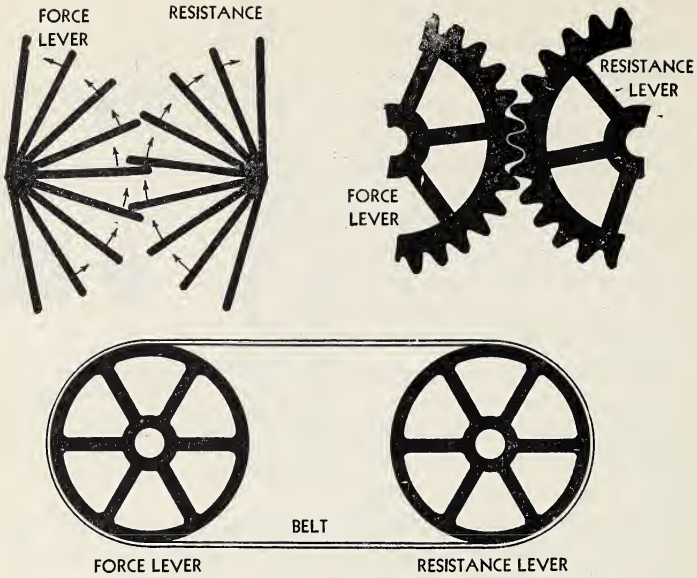
The steelyard balance has unequal arms. If the distance between the hooks is one-ninth as great as the distance from the middle hook to the weight, what does the ham weigh?

Sometimes the fulcrum is at the end, but the force is applied in the middle of the lever instead of at the end. This is the situation when we use a spade for digging. The hand on the end serves as a fulcrum, while the other hand on the handle provides the force. The resistance is on the blade of the spade.

You can understand better the positions of the force, resistance, and fulcrum by studying the diagram on the opposite page. The first lever is similar to the teeter board, the second to the pry pole or wheelbarrow, and the third to the shovel, broom, or fishpole.

More than half of all machines are levers. Many other machines which seem much different from levers on first thought are really more complex arrangements of one or more of the forms of the simple lever.

Is a wheel and axle a lever? A special type of lever is called the wheel and axle. If you have a spool on which a thread is wound, you can wind on more thread by turning the rim of the spool. If a weight is hung from the thread, you can lift it up by winding up the thread. The center of the spool is the fulcrum. The force is applied at the rim of the spool. The point from which the thread is suspended is the resistance.



Gears and pulleys are really levers. If you study these diagrams you can see that the levers of one wheel turn the levers of the other wheel.

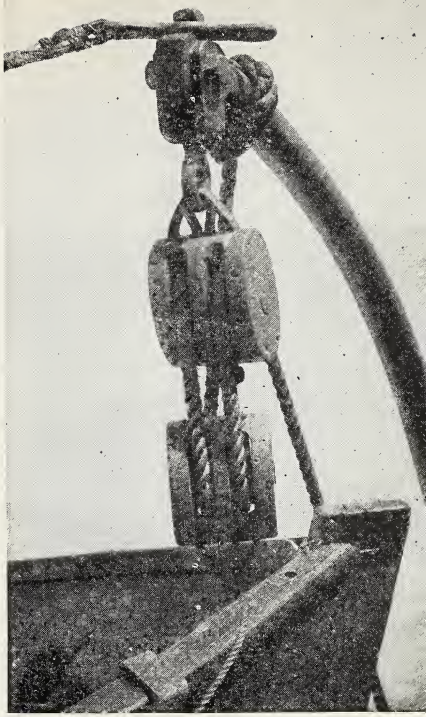
The automobile steering wheel is also an example of a wheel and axle. The force is applied at the rim of the wheel. The rod which supports the steering wheel offers the resistance. The axle of the steering wheel is attached to other simple machines to turn the wheels of the automobile.

In digging wells men often use a wheel and axle to lift soil and rocks from the hole. The "wheel" has only one spoke, the stick to which the handle is attached. A tool grinder which is turned by a crank is another type of wheel and axle. The food grinder and egg beater also use the wheel-and-axle type of lever. All belong to the second class of levers shown on page 366. Can you explain why?

How do pulleys work? If a pulley is used to support a rope to raise an object attached to one end of the rope, it is a lever of the seesaw type. The axle of the pulley is the

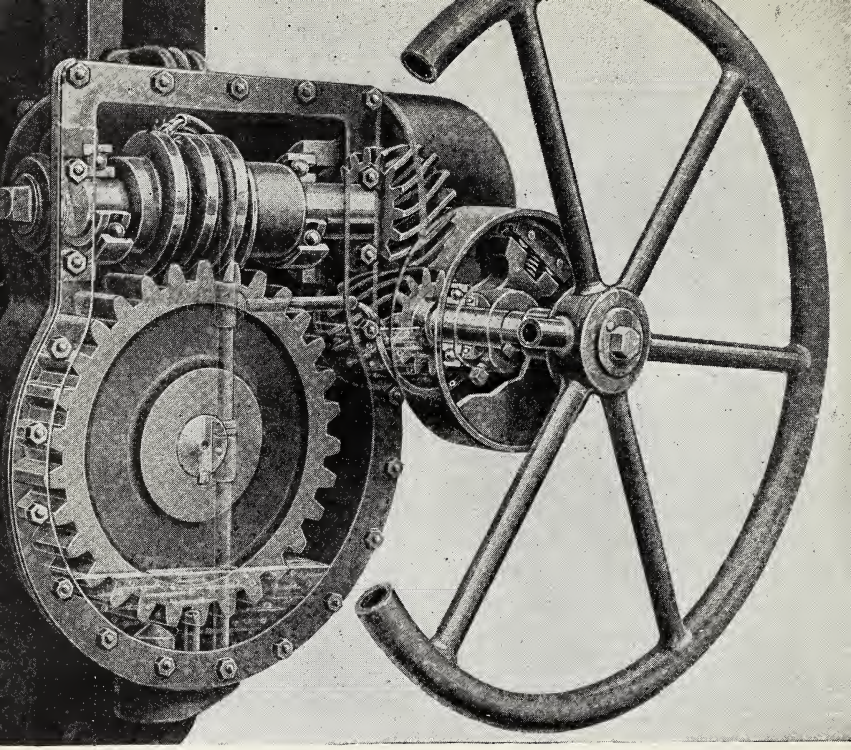
fulcrum. The resistance hangs from a rope on one side of the pulley, while the force is applied to the rope hanging from the other side. Since the spokes of a wheel are of equal length, the only advantage gained by the use of one fixed pulley is to change the direction from which the force is applied.

The pulley may be supported on the rope so that it can move up and down, and one end of the rope is attached to a support. Then the weight is hung on the pulley, and not on the end of the rope. In this way two ropes are made to support the weight, each one holding up half the weight. A person pulling on one rope need apply a force equal to only half the weight to raise it. But in doing so, however, he must pull two feet of rope through the pulley for each foot the object is lifted. While he gains in force, he loses distance.



The lifeboat is suspended by ropes running through pulleys. One pound pulling on the rope will lift four pounds on the lifeboat. Also, the use of pulleys and ropes makes possible lowering the boat where men could not reach.

Pulleys are used more commonly than most people think. Every well-made wooden window frame in which the windows can be raised and lowered contains pulleys. A pair of pulleys is located at the top of the frame for each half of the window. Ropes are run from the window sash over the pulleys to weights inside the frame. If the weights are correct, they will just balance the weight of the window. If the cord supporting the window should break, you will discover how



Courtesy Whiting Corporation

This drawing of gears is made so that you can see inside a machine. These gears are somewhat more complex than usual. Note that the gears are washed with oil to reduce friction.

difficult it is to open a window that does not have weights.

Pulleys are also used on boats of all types. Lifeboats are supported by pulleys. To lower the lifeboat, it is only necessary to untie the loose end of the rope. The weight of the boat will cause it to go down. In lifting the boat from the water, it is necessary to pull all of the rope back through the pulleys. If it is 10 feet to the water, 40 feet of rope will be necessary to go through a set of pulleys using four ropes. It will be necessary to apply the needed force through 40 feet to raise the boat 10 feet. However, if the boat weighs 1000

pounds, only 250 pounds of force would be needed, providing there was no friction. Since there is considerable friction, more force than one-fourth of the total weight will have to be used. The advantage which is gained by the use of pulleys can be determined by counting the number of ropes which actually support the weight.

What are gears? Sometimes the rim of a wheel has notches cut in it in such a way that they will fit into similar notches of a second wheel. As power is applied to either the rim or axle of one wheel, it will be carried to the rim of the other wheel. Such wheels are called gears. At first thought, they may seem to be very different from levers. Yet whether the gear wheels have separate spokes or not, the point at which the contact [touching; coming together] is made with the second gear is one end of the lever. If the gears turn, the point of contact remains in one place, but different parts of the gear make the contact. By using gear wheels of different sizes, both the speed and the amount of force applied can be controlled. If the second gear is to turn faster than the first, or driving, gear, the second, or driven, gear is made smaller than the first. But if more power is needed, the driven gear is made larger than the driving gear. The smaller gear always turns faster than the larger gear, but the larger gear always has more power.

How are combinations of levers used? Machines contain many wheels, gears, rods, and axles. If you examine some machine, you can discover that nearly every part is some adaptation of the simple lever. Belt wheels, gears and shafts, and wheels and axles are all levers. Where the rotation of a wheel is to be changed to a back-and-forth motion, a lever is always used to produce the back-and-forth motion. Examine the next machine you see to find how many adaptations of the lever you can recognize.

DEMONSTRATION. HOW DOES A LEVER WORK?

What to use: Ruler, weights, ring stand, spring balance, string.

What to do: Support the ruler at the middle, so that it balances. Hang the spring balance below one end of the stick, and hang a weight at the other end. Hold the balance to keep the stick level, and note the force required. Move the weight toward the center of the stick. Note the readings of the balance each time the weight is moved.

Remove the ruler from the ring stand, and fasten the weight near the middle of the ruler. Put one end of the ruler on the edge of the table and support the other end by lifting it with the balance. Move the weight first toward the balance, and then toward the table edge. Note the changes in the reading of the balance.

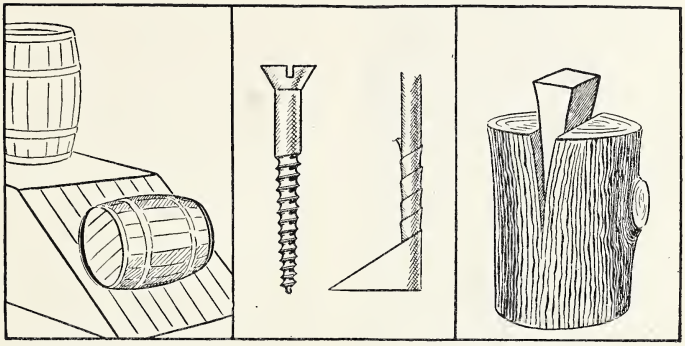
What was observed: Which lever is like a teeter board? Which is like a pry pole? When the distance from the turning point (fulcrum) of the lever to the weight is increased, what change takes place in the reading of the balance?

What was learned: What is the relation between the distances on a lever, the amount of weight used, and the force required to support the weight?

——Things to think about——

Select the correct word or words needed to complete each of the following sentences. Do not write in this book.

1. A wheel and axle is the same type of lever as a (*a*) seesaw (*b*) wheelbarrow (*c*) shovel.
2. We use crowbars because they (*a*) move things rapidly (*b*) permit us to use a small force to move large objects (*c*) are light in weight.
3. A gear is really a kind of (*a*) wheel (*b*) tool (*c*) lever.
4. Pulleys are used with belts to (*a*) carry force from one place to another (*b*) lift boats (*c*) reduce friction.
5. On a seesaw the larger person sits (*a*) nearer the cen-



There are three forms of the inclined plane. The first is the skid. The second is the screw, which is an inclined plane wrapped around a rod. The third is the wedge.

ter (*b*) farther from the center (*c*) where he chooses because he is bigger.

6. Windows are balanced with weights by the use of a (*a*) wheel and axle (*b*) pulley (*c*) lever.

7. The point around which a lever turns is the (*a*) end (*b*) center (*c*) fulcrum.

8. In its simplest form the lever is a (*a*) wheel and axle (*b*) straight rod (*c*) pulley.

9. In a single movable pulley the weight is supported by (*a*) the force exerted (*b*) both ropes (*c*) a single rope.

——Science activity for fun——

Bring a lever machine to school and demonstrate its use.

4. What advantages are obtained by using an inclined plane?

When we walk up a hill or a flight of steps, we are using a sloping surface to raise a weight. Such sloping surfaces are called inclined planes. Of course steps are not planes, but are notches in a plane. When one considers that sur-

Photo Pilatus-Bahn, Eselwand, Switzerland

Most roads are inclined planes, but few are as steep as this railroad in the Swiss Alps. The track has three rails, and the wheels have cogs to prevent them from slipping.

faces are rarely level, this method of raising or lowering weights is one of the most widely used of all devices. A commonly used incline plane is a short plank used to raise heavy objects such as barrels to the floor of a wagon or truck.

How are inclined planes used for roads? Where a road passes over a hill, it is necessary to lift a load against the force of gravity to a distance equal to the height of a hill. Since the steepness of the grade which a car can climb is limited, roads are planned to make the slope as gradual as possible.

But regardless of how long the hill may be, the effective work done consists of moving the load through the vertical (up and down) distance to the top of the hill. Sometimes it is necessary to build miles of winding road in order to keep the slope gradual and at the same time get over a hill. Less force is required to overcome gravity on a gentle slope than on a steep one.

It is very important that roads be made of smooth, hard materials. If the road material is soft, wheels sink into it and must be constantly lifted from the hollow places which they make. As the wheel turns, it is constantly rolling up the sloping side of the hollow place. When a load is lifted out of a rut or over a stone, work must be done.

Railroad tracks are built with even more gradual slopes

than those used for automobile roads, since the load which the engine must lift is much heavier. If the slope is too steep, the wheels of the engine slip on the rails. In some places where it is desired to transport people and materials through a short distance to the top of a mountain, a steep inclined plane is used to lead directly to the mountaintop. Since it is so steep that the friction of the wheels will not hold the load, cogwheels are provided to pull the locomotive up the hill, and the other wheels are used only to support the weight.

How is wood split with an inclined plane? The most common inclined plane of all is the wedge. The wedge has a narrow edge which can be driven into wood or cracks between objects. The sides of the wedge slope. As the wedge is driven in, its sides push against the objects to force them farther apart. A knife blade is a wedge. If you place the blade with one side flat on the table, you can easily see that the other side slopes upward to make an inclined plane. A wedge is used in cutting stone. As it is driven into a small crack or against the surface, the parts of the stone are pushed aside.

Woodsmen use a wedge to drive into the crack made by the saw in cutting down a large tree. Without the wedge the weight of the tree tends to close the cut and pinch the saw. A carpenter's chisel and a doorstop are common and useful wedges. Some wedges do not have flat surfaces, but are rounded. A needle is a round wedge. As it enters a tiny opening in the cloth, it forces the threads apart. Pushing aside the threads of the cloth is work—a force acting through a distance.

How are screws able to help us to work? If you examine a screw, you can see that the thread runs around the central rod so that each turn rises above the last. If you will cut a triangle out of a piece of paper and wrap it around a pencil beginning with the square end, you will have a slope like the thread of a screw.

As the screw is turned, the edge of the thread cuts into the wood and the incline serves to pull the screw into the wood. Because the friction between the edge of a screw and

Courtesy Spokane Chamber of Commerce

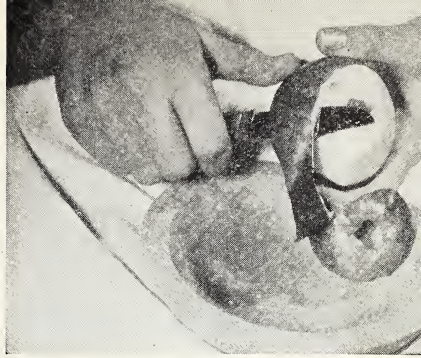
The skid is used in loading logs on a truck. A chain attached to the truck is passed under the log and over the truck. A team of horses pulls the chain which rolls the log on the truck. Note the levers the men are using.

the wood is very great, screws are useful in holding pieces of wood together.

The carpenter's bit is another inclined plane. It has a knifelike edge which cuts a shaving, and an incline which lifts the shaving from the hole as the bit turns. The point of the bit is a screw which draws the cutting edge deeper into the wood.

A screw is used in a coal stoker to force the coal through a pipe and into the bottom of the furnace. This screw must be made very strong to move any but small-sized pieces of coal through the pipe.

The common fruit jar and many bottles are made with screw tops to keep the lids tightly in place. Light bulbs screw into sockets to hold the light bulb tightly against the contact. Fountain pens have caps screwed on the pens. How many other uses of screws can you list?



Even so simple an inclined plane as a paring knife requires skill in use. Peeling an apple with the wedge-shaped blade is not so easy as it looks.

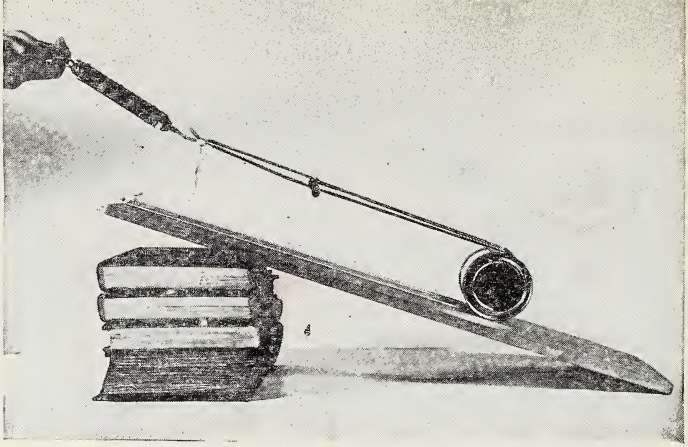
How can combinations of inclined planes and levers be used? In some places you may read the statement that there are six simple machines: the lever, the inclined plane, the screw, the wedge, the wheel and axle, and the pulley. We have seen that these really are all either levers or inclined planes. Remember that the wheel and axle and pulley are really levers. It is difficult to realize that all machines are made up of many arrangements of these two simple machines. For example, a wood saw is a series of wedges arranged along a blade or circle of steel. The round saw is turned by the shaft, which applies the force to the teeth of the saw by use of a lever. The pulleys which apply the power are levers.

So it is with all machines. If you study every part, you can find in it either levers in some form or inclined planes in some form.

Demonstration. How Does an Inclined Plane Work?

What to use: Board about three feet long, baking powder can, weights, tacks, string, spring balance.

What to do: Support one end of the board on books. Attach two strings, twice as long as the board, to the upper end of the board with the tacks. Pull the strings tight along the board to the lower end. On top of the strings, lay the baking powder can filled with weights



What two simple machines are combined in this demonstration setup?

and tightly covered. (If the weights shift about, stuff the can with paper.) Bring the loose ends of the string back over the can and attach them to a balance. They may be kept spread apart by tying them to a pencil. Then pull the strings to roll the can up the board with the spring balance and note the force required.

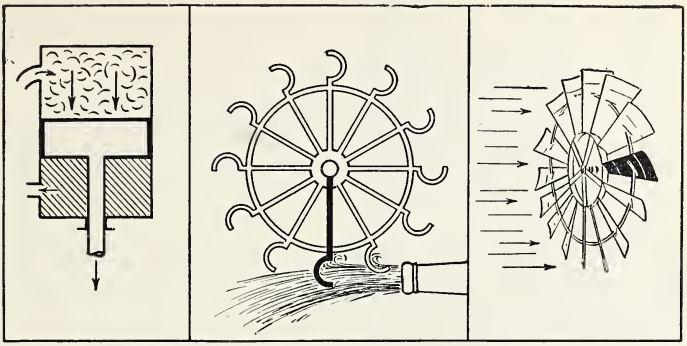
Raise the end of the board, and again pull the strings to roll the can upward. Note the force required. Again raise the board, and note the force required to roll the weight upward. Remove the can from the board, and weigh it.

What was observed: Does the force required to roll an object up a skid increase or decrease as the end of the board is lifted? Can you explain how the can and string act as a pulley? Does the weight of the can equal the force required to raise it up the skid?

What was learned: What is the relation between the slope of an inclined plane and the amount of force required to lift an object with it?

——Things to think about——

Complete the following sentences. Do not write in this book.



There must be a surface against which force may be exerted—a "handle." The piston and cylinder are used in the gasoline engine, in the steam engine, and in many pumps. The water wheel and windmill are familiar devices for providing a surface against which force acts.

Two simple machines which are inclined planes are the —1— and the —2—. When an inclined plane is used, a —3— force is required, but the force must act through a —4— distance. All —5— machines are made up of adaptations of —6— simple machines. Winding roads are sometimes built up hills in order to keep the —7— gradual. If a mountain is very steep, —8— are sometimes used to pull a locomotive directly up the slope. Some wedges, such as a needle, have —9— surfaces. The —10— of a screw help to pull it into the wood.

5. How do machines apply energy to do work?

We have been thinking of doing work in terms of using our own muscles to move levers or to pull ropes through pulleys or to roll barrels up inclined planes. Yet we know that most of the work of the world is not done by man's muscles at all. Our muscles are unable to supply much force, compared with the force of the wind or of a mighty waterfall. Nor can we compare our strength with the force of steam in a boiler or of gasoline exploding in an engine.

What is energy? We may define *energy* as the ability to do

work or to bring about changes. We are familiar with many forms of energy. Heat, light, and electricity may be used to produce changes in matter to cause it to move.

The energy of heat stored in gasoline or steam must be applied as a force before it is capable of doing work by operating engines. Heat may also evaporate water and lift it to the mountaintops, from which it flows as a river capable of doing work.

How is energy related to force? You know that force is a push or a pull. If energy is applied to some object on which it can push or pull, force is exerted [put forth].

If water is stored behind a dam, it has energy stored in it. Because the dam presents a flat surface against which the water can act, force is exerted on the dam. Yet no work is done by stored water, for neither the water nor the dam is moving. Such stored up energy is called potential [pō·tĕn′-shăl] energy. Potential energy stored in water really comes from the sun and the force of gravity.

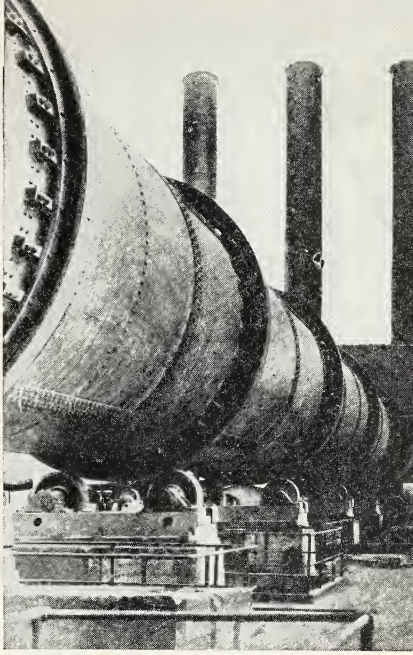
If the water flows over the dam, it still contains the energy but in a different form. The energy of any material in motion is called kinetic [kĭ·nĕt′ĭk] energy. As the moving water strikes various objects in its path, it exerts force upon them.

How is the force of running water used to do work? Before running water can do work, we must provide some surface against which it can push. The simplest practical device for using the force of running water is the water wheel. It consists of a wheel with blades projecting from the rim. The wheel is firmly attached to its axle. When water falls upon the wheel, it strikes the blades or paddles which serve as levers to carry force to the axle. The axle turns and carries the force to a machine. The machine most often turned by a water wheel in olden days was a flour mill in which wheat was ground beneath a slowly turning stone. The pressure of the upper stone and the friction of the upper stone turning against the lower stone combined to reduce the grain to powder.

Today water wheels are still in use, but are generally

employed to turn machines which produce electric currents.

The amount of work which can be obtained from running water depends upon the height from which it falls. Since water weighs 62.4 pounds per cubic foot, every cubic foot of water is able to do 62.4 foot-pounds of work for each foot that it falls. Water wheels do not obtain all the potential energy from the falling water, for much of the water falls off the ends and sides of the blades before it has given up its energy.



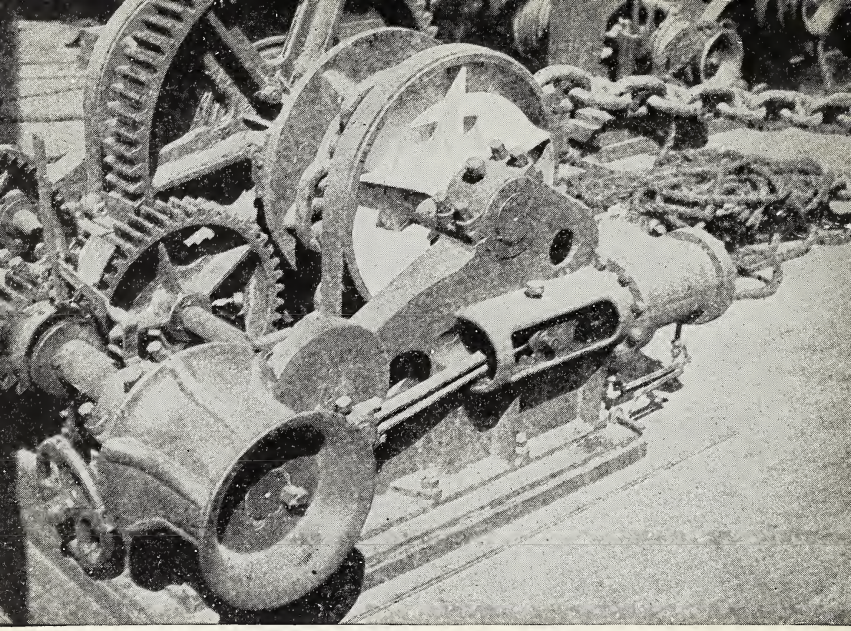
Courtesy Universal Atlas Cement Co.

One of the world's largest machines is this lime kiln, which slowly rotates as flames shooting through it change limestone into carbon dioxide and lime.

How is the force of wind used to do work? It is impossible to make a practical windmill with the blades set in the same position as those of the water wheel. Instead, the blades are set at an angle. Water flows over the water wheel along the rim, but wind flows through the windmill wheel in a direction parallel to the axle.

Each blade of the windmill is an inclined plane. As the wind pushes these blades, called vanes, they produce a force which tends to turn the wheel. The turning wheel is attached to a crank, much like the crank to which your bicycle pedals are attached. Attached to the crank there is a rod which leads downward to the pump. As the wheel turns, the rod is moved up and down, and the pump lifts water from the well.

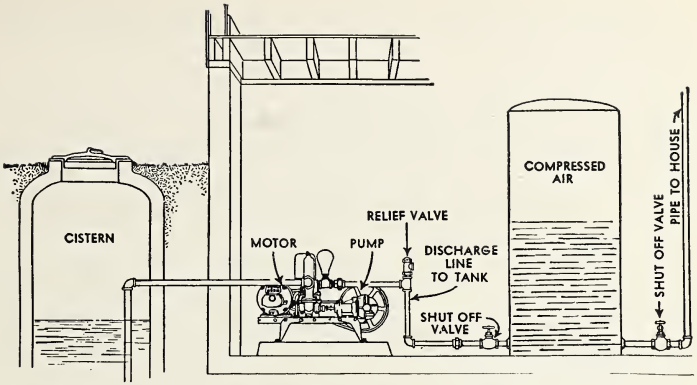
How are expanding gases used to do work? Whenever a gas is under pressure, it tends to expand. If the gas is per-



The small steam engine is used to hoist loads on a wharf. At the right of the engine is the cylinder, inside which the piston is pushed back and forth by steam. Steam comes from a boiler beneath the wharf. The piston moves a rod attached to the solid wheel.

mitted to expand, it gives off the energy used to compress it —whether the energy be obtained by heating the gas or compressing it with a pump. This energy may be converted into a force which is useful for doing work.

Steam is compressed by the energy put into its molecules when the water is boiled. Steam is confined in a boiler to maintain its pressure. To use the pressure of steam, it is permitted to flow from the boiler into some kind of machine which provides a surface on which it can exert force. The standard steam engine consists of a piston and a cylinder. The piston slides back and forth when steam is admitted to the two ends of the cylinder alternately. When steam is let into one end of the cylinder, the steam behind the piston is permitted to escape. Thus there is always a difference in the



This type of home water system is used in thousands of houses where city water is not available or where the supply of city water is not soft. Rain water from the cistern may be kept under pressure in this system.

pressures of the steam on the two ends of the piston. There are three common arrangements of valves used to permit steam to enter and leave the cylinder, and all are complex in their operation.

When gasoline explodes in a gas engine, gases under pressure are formed. The gas engine also consists of a piston moving in a cylinder. All piston-and-cylinder engines carry force from the piston through a connecting rod to a crank. A piston is really the enlarged end of a lever.

How does compressed air do work? You already know several ways in which compressed air does work. Another interesting compressed-air device is found in one type of a home water system. An airtight tank is used for storage of water. The water is pumped in at the bottom, and as it enters the tank, the air in the upper part is compressed. By the time the tank is about half full of water, there is enough air pressure to force water to run through pipes from the bottom of the tank to the second story of an ordinary house. As the water runs out, the air expands, and its pressure decreases. Then more water must be pumped into the tank to increase the pressure.

In this water system, the force is applied against the surface of the water.

Demonstration. How Does Expanding Gas Exert Force?

What to use: Heavy-walled test tube, cork stopper, burner, ring stand and clamp.

What to do: Fill the test tube about half full of water. Put the stopper into the test tube and fasten it on the ring stand. Apply heat and stand back. (*Caution: Do not insert the stopper too tightly.*)

The same result can be obtained by putting a piece of dry ice in a heavy pop bottle, and letting it stand a few minutes after the stopper is inserted.

What was observed: How does the tightness of the cork affect the result? Why is there some danger that the test tube may break?

What was learned: Explain how the energy of the flame was changed into a force by the steam, and how work was done.

——Things to think about——

Complete the following sentences. Do not write in this book.

Force is either a —1— or a —2—. Force is exerted upon the —3— of a steam engine, upon the —4— of a windmill, and upon the —5— in a home water system operated by compressed air. Circular motion is changed to back-and-forth motion by a —6— turned by a windmill wheel. Back-and-forth motion is changed to circular motion in a steam engine by a connecting rod turning a —7— which carries force to the flywheel. —8— energy is stored in water behind a dam, and is changed to —9— energy when the water starts flow-

ing. —10— is that which is capable of producing change or causing movement.

——Science activities for fun——

1. Make a model windmill. Use strips of metal cut from a can for blades, and a spool for a hub. Mount the spool on a nail. Cut slits in the spool, and force the blades into them. Twist the blades to make vanes.

2. Make a model water wheel. There are many materials you can use, and several ways of making the wheel. Plan a method for yourself.

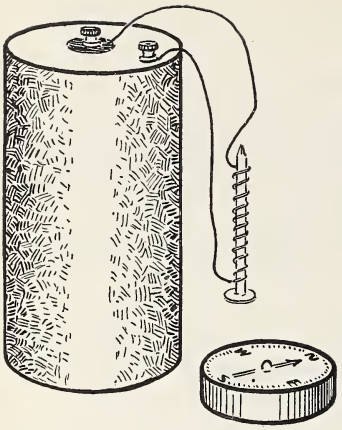
3. Make a model compressed-air water tank. Use a large test tube, a two-hole stopper, and glass tubing. Why can you not force the water into the tube halfway?

6. How can electricity exert force?

One of the most convenient sources of energy is electricity because electrical energy can be carried through wires or obtained from batteries which can be moved to the place where the power is needed. Because it is so easy to control devices operated by electricity, it is perhaps the most useful source of power known.

What are some sources of electricity? Electricity may be obtained from dry cells, storage batteries, or dynamos. The dry cell is made up of a zinc container which is filled with certain chemicals, some inactive substances, and a centrally located carbon rod. The materials are not really "dry." The chemical action which takes place requires some moisture, but no free water need be present. The carbon rod and the zinc have bolts fastened to them which are used as binding posts to which the wires may be attached. The electricity is produced as a result of certain chemical changes which take place within the cell, and the resulting current flows through the wires.

What effects do electric currents have? Most of you have played with a magnet at some time. The ordinary magnet is a piece of iron or steel which has the property of attracting



Any wire carrying a current will affect a compass needle. The effect is greatly increased by winding a coil of wire on a soft iron core.

other pieces of iron. If a bar magnet is hung up by a string so that it can turn freely, one end will point north. We say that this is the north pole of the magnet. The other end which points in the opposite direction is called the south pole. A special type of magnet which is balanced on a needle point so that it can turn freely is called a compass. With such a device, one can determine the direction in which he is traveling.

When the north poles of two magnets are held together, they repel [push away] each other; but when the north pole of one magnet is near the south pole of another, they attract each other. They actually move together if the resistance between is not too great. The compass needle turns toward the north pole because the earth itself is a magnet. The so-called north pole of the compass is really a north-seeking pole.

If an electric current flows through a wire, a magnetic force forms around the wire. If the compass is brought near a wire carrying a current, the needle turns from its normal position. This movement shows that the ends of the magnet are being attracted by a magnetic force stronger than that of the earth.

If the wire is placed in a horizontal position and the magnet held above it, the compass needle will point in one direction; but when placed below it, it will point in the opposite direction. You can do this experiment with a dry cell, a piece of wire, and a compass.

The amount of magnetism around a single wire is small.

Courtesy Whiting Corporation

Two types of machines are combined to handle scrap iron. The beam travels on wheels along the track, and on the beam a crane moves back and forth. The crane supports an electromagnet which picks up and holds iron when a current flows through it.

To make use of the magnetism of an electric current, many turns of wire are wrapped around a hollow core, as thread is wound on a spool. If the compass is held inside such a coil of wire and the current is turned on, the compass needle is turned to a new position very rapidly. The more turns of wire which are used, within practical limits, the stronger the force will be.

How can you make an electromagnet? If a bar of soft iron is placed within a coil of wire carrying a current, the strength of the magnetism is increased. Magnetism flows more readily through iron than it does through air. You can construct an electromagnet which will have considerable power. Wind a coil of doorbell wire around an iron core. A large nail will do for the core. The wire must be covered with an insulator [ĭn′sŭ·lā′tẽr, a material which will not conduct electricity]. If uninsulated wire is used, the bare wires touching together act as though they were a single wire.

When you have wound the wire around the nail, you will need a source of direct current. A direct current is one which flows in one direction. A dry cell supplies a direct current which is not strong enough to be dangerous for use in experimentation. When two ends of the wire leading to the coil are attached to a dry cell, the magnetism will be sufficiently strong to lift many small objects made of iron and steel.

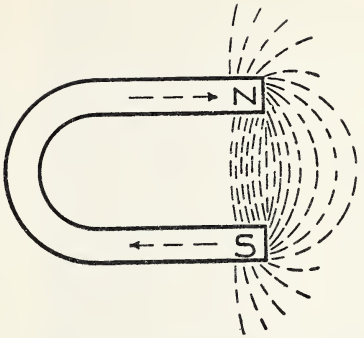
How can an electromagnet be used to do work? If a switch is connected between one of the binding posts of the dry cell and one of the electromagnet, the current can be turned on and off readily. When the current is off and the electromagnet is placed near a piece if iron, it will do no work. If the switch is closed so that current can flow through the wire, the electromagnet will pull the iron toward it with considerable force. Moving an object through distance is work, and in this way the electromagnet does work.

How can an electromagnet be made to push as well as to pull? A second electromagnet made like the first one will be magnetized when connected to a dry cell. When the poles of the two electromagnets are brought together, they are attracted strongly if they are unlike. If they are like poles they are repelled from each other. By turning off the current in one of the electromagnets, it will lose its magnetism and no longer will repel the other magnet. From this we see that an electromagnet can be used to cause another electromagnet to turn away from it.

An electric motor consists of two sets of magnets. One set is firmly attached to the base. The other set is attached to a shaft, and is rotated by the attraction and repelling forces set up by the magnets. The outer, rigid magnets are called field magnets; the rotating magnets are called the rotor. Electric motors are the most common source of power in most homes.

How can a permanent magnet be made? The ordinary method of magnetizing a piece of iron, such as a knife blade, is to rub a magnet over its surface. Such a magnet may soon lose its magnetism. However, a magnet can be made quite

permanent by rubbing a piece of hard steel with the end of an electromagnet, or by inserting it into a coil consisting of many turns of wire. In the latter case the steel should be tapped with a hammer to help the molecules of iron adjust themselves to the magnetism. If the magnet is made by rubbing steel with the end of an electromagnet, the strokes should always be made in the same direction and with the same end of the electromagnet touching the steel.

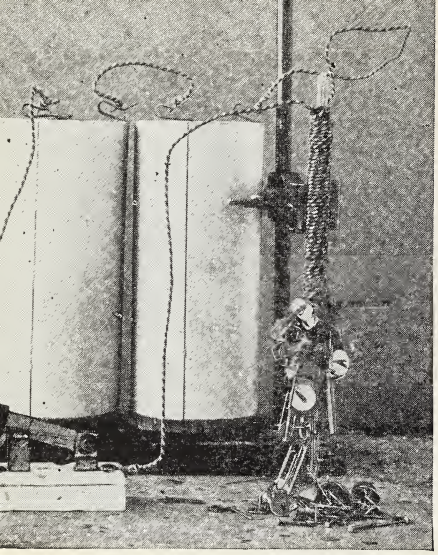


The direction of lines of force around a magnet may be found by use of a small compass and drawn on a sheet of paper as shown in this diagram.

How are simple magnets used? Because electromagnets are much stronger than permanent magnets and can be turned on and off, they have many more uses than simple magnets. Permanent magnets, however, may be used in many ways. If you magnetize a darning needle and thrust it through a cork, it can be used as a compass when placed in some water. Such a compass can be used to test wires to see if they are carrying a current and to find the direction of the north magnetic pole. It also can be used for many other experiments with electricity.

Sometimes tack hammers are magnetized so that a tack will stay on the head of the hammer. To use a magnetized tack hammer, a tack should be placed on the head of the hammer and driven with one blow. Sometimes it is very convenient to have scissors magnetized so that they can be used to pick up steel pins and needles. Your mother may not wish to have her scissors magnetized, however, since needles tend to stick to the scissors when you don't want them to.

Magnets are used in beauty parlors, also, to remove hairpins from women's hair.



This is the electromagnet which you can make. In addition to the use for lifting iron and steel objects, there are other uses. You can magnetize needles for use as compasses and magnetize hammers to hold tacks.

What care must be taken in using electricity? To work around electric currents larger than those supplied by dry cells requires special precautions. The following statements are good rules to follow:

1. Never try to repair or handle any wire or piece of equipment which carries a current.
2. Do not touch any electrical equipment with wet hands.
3. Do not let any bare wire touch any bare metal, such as nails or pipes.
4. Remember that your vacuum cleaner, refrigerator, radio, heating pad, iron, or toaster may burn the house or kill someone from shock. Handle them with care.

Demonstration. How Can Electricity Exert a Push or Pull?

What to use: Dry cells, doorbell wire, large nails, small nails.

What to do: Wrap a nail tightly with the covered doorbell wire to make an electromagnet, with about a foot of wire projecting at each end. Attach the ends of the wire to the dry cell, and see if the nail will lift other nails. Disconnect it.

Make another electromagnet. Connect both, and bring them together end to end. Observe if they attract or repel each other. Change the position of both

electromagnets, end for end. Change one electromagnet, end for end; leave one unchanged. Repeat until you know which ends repel and which attract.

What was observed: How many nails can be picked up by using one electromagnet? Can you arrange two electromagnets to make them lift more than one will? Are you positive that electromagnets will repel?

What was learned: Answer the question at the beginning of the demonstration.

——Things to think about——

Complete the following sentences. Do not write in this book.

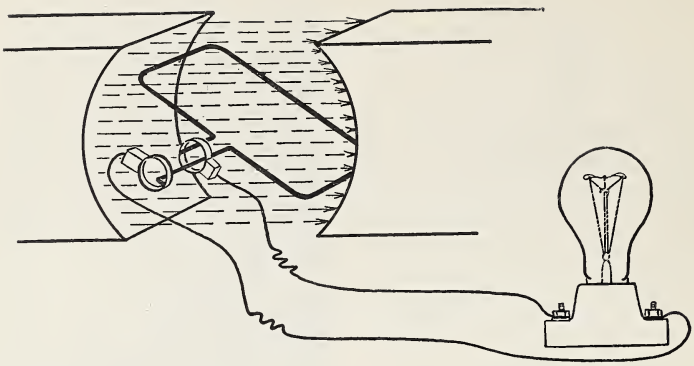
Electricity is a form of —1—. Around every current there is a —2— field. A nail, a wire, and a dry cell can be used to make an —3—. North and south poles —4— each other, but two north poles, or two south poles, —5— each other. Inside the —6— of an electromagnet there is always a core made of —7—. When one touches a bare wire carrying a current, he may suffer from —8—. —9— current is one which flows in one direction. A substance which will not conduct electricity is called an —10—.

——Science activity for fun——

Obtain a strong magnet, or make an electromagnet, and make yourself a compass. Also magnetize some common tools. Test a wire carrying a current with your magnet.

7. How is electricity used?

Electricity is the most convenient of all sources of energy for doing work in the home. About half the houses in the United States are provided with electricity. Some of the devices we use in modern houses depend upon electric motors to supply force; some depend upon the use of electromagnets; and others depend upon the fact that an electric current flowing through a wire produces heat.

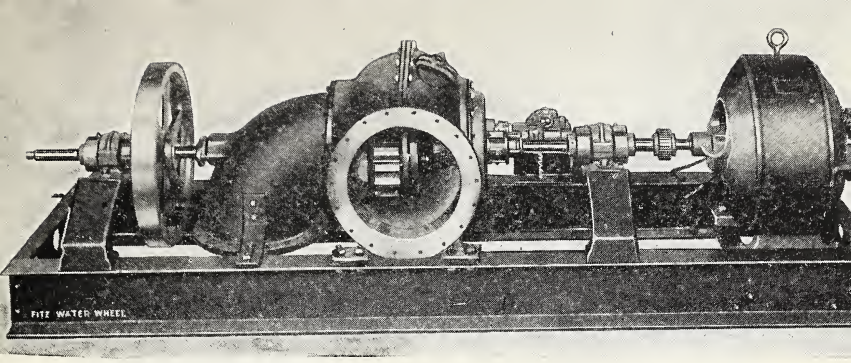


The dynamo works on the principle that a loop of wire turning between magnets may make a current. Actually, hundreds or thousands of loops of wire make up the coils in dynamos. Each end of the loop is attached to a ring which slides against a metal brush connected to the wires leading to the lamp.

How is our house current produced? You know that the electricity we use in our homes does not come from dry cells. The wires which lead from poles outside the house carry current from a distant power station.

The machines which produce current in the power station are called dynamos. A dynamo is constructed in much the same way that a motor is. It consists of immovable field magnets and a rotor. The rotor is made up of coils of wire wound on soft iron cores. The operation of a dynamo is just the opposite of that of a motor. In a motor a current flows into the coils, the work is done by the moving coils. In a dynamo work from some outside source is done to turn the coils, and a current flows out of the rotor coil.

If you make a coil of wire and connect the ends of the wire to a sensitive meter, you can show the presence of a current produced by moving a magnet through the coil. A current can be produced only when either the coil or the magnet, or both, are moving. Thus you see that electrical energy can be used to do work, or that work can be used to produce electricity.



Courtesy Fitz Water Wheel Co.

The machine on the left is a small turbine, and the one on the right is a dynamo. This type of machine is used in small villages and on farms where running streams furnish power. The dynamo produces electricity.

The coils of a dynamo are rotated by power from a turbine or from a water wheel or from a steam engine. Dynamos of farm lighting systems are turned by windmills or by gasoline engines.

The method of taking off the current from the whirling rotor is not easy to understand. There are a number of contacts, two for each coil in the rotor, which turn against connections leading to the power lines. Electricity is carried through copper wires from the dynamo to the various places where it is needed.

How are electric motors used? When we consider the work it does, the electric motor is in many ways the most remarkable machine ever made. The largest motors made provide power to pump water in the Grand Coulée irrigation project, while the smallest motors built will fit into a thimble. Tiny motors are used in dentists' drilling tools. Trains are operated by power from electric motors.

Many of the common household machines obtain their power from electric motors. The electric fan is a motor and fan. The vacuum cleaner contains an electric fan in the nozzle of the cleaner. The washing-machine motor lightens the heavy work of washing and wringing out the clothes. An electric motor operates the pump which forces oil into the

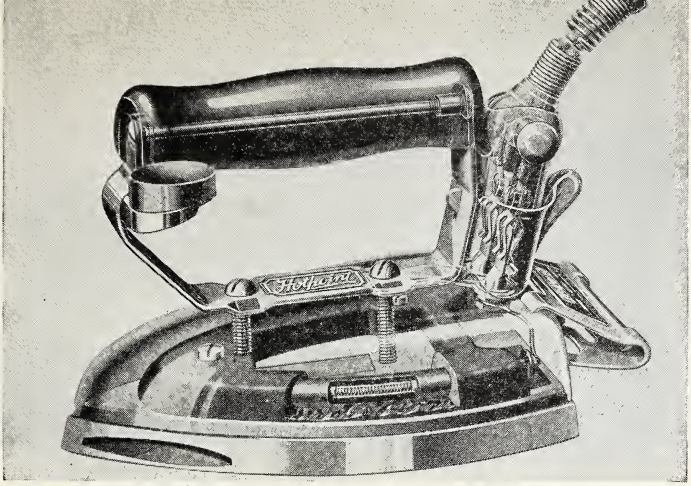
firebox of an oil burner, and operates the fan which provides the draft for the fire. Coal stokers are operated by electricity. Electric clocks contain tiny motors. Food mixers and hair driers depend upon electric motors for their power.

In many industrial plants electric motors have replaced other sources of power. In old-time factories steam engines turned long shafts from which many belts were run to operate machines in various parts of the factory. There was constant danger of a belt slipping from its pulley and injuring someone. Time was lost in replacing and in repairing belts. The belts were in the way of easy movement. Modern machines are operated by electric motors built into the machine.

How is electricity used to produce heat? Whenever electricity flows through any material, some heat is produced, because all substances resist the flow of a current to some extent. An electric circuit is made up of a complete system of wires without any breaks in it. In any circuit the different wires which make it up have different resistances. The wire which has the greatest resistance in any circuit becomes the hottest. For example, let us study the toaster. The wire in the toaster and the wire in the cord make up this particular circuit. The cord wire, which is of copper, offers comparatively little resistance to the current and remains cool. The heating unit in the toaster is made of a highly resistant wire, and becomes quite hot.

The tiny filament which glows in an electric lamp bulb is made of resistance wire. While it is not designed to produce heat, it must get hot to give off light. The wire is so hot that it would burn if there were any oxygen in the bulb. Small lamp bulbs are generally made by pumping out most of the air, but larger bulbs are filled with nitrogen and other gases that will not combine with the filament of the bulb.

The electric iron is another device employing resistance wire. The wire most commonly used is nichrome [nĭk′rōm], the same kind of wire that is used in toasters. Nichrome is a metal made up of a mixture of iron, nickel, and chromium. The nichrome wire becomes so hot that it must be shielded



Courtesy General Electric Co.

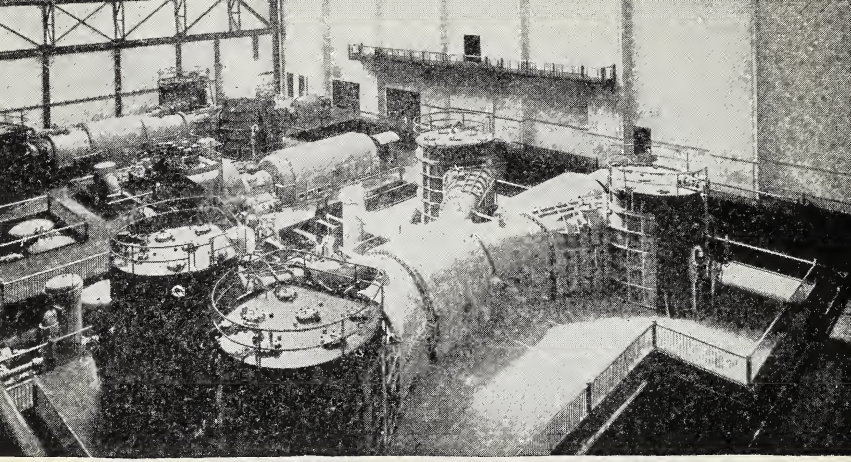
If your electric iron were transparent, it would look like this. The working part of the iron is the coil of wire which is heated by the current flowing through it. How many parts has the iron?

with insulation to prevent it from heating parts of the iron which might cause severe burns. Insulation is also used in the iron to prevent the wire from carrying current to the outside of the iron and causing dangerous shocks. The insulated heating element is placed between two heavy pieces of iron, one of which forms the shoe, or bottom, of the iron. By locating the heating element properly within the iron, it is heated evenly.

Some irons are made safer to use by means of a thermostat [thûr′mō·stăt]. When the iron becomes as hot as is safe, the current is automatically turned off until cooling takes place. As the iron cools, the current automatically turns on before the material becomes cooler than needed. Irons without this safety device should be operated with a pilot light attached in the circuit so that one can see the light if the current is on.

Electrical heating devices are not machines—that is, they do not apply force to do work. They do, however, make it more convenient to do work in many ways.

How can we avoid dangerous amounts of electricity? The



Courtesy General Electric Co.

If you live in the neighborhood of Hammond, Indiana, your light current may come from one of these dynamos, which are turned by turbines. These huge turbines and dynamos work on exactly the same principle as the loop shown in the diagram on page 266 and the small farm plant shown on page 267.

amount of current which a given wire carries determines the amount of heat produced in a wire. The amount of current which flows in the house wires depends upon how many resistances are connected between the two sides of the circuit. Each time a lamp or other electric appliance is connected between the same pair of house wires, an additional path is provided through which the electricity can flow. It is possible to connect so many appliances that the amount of current flowing through the house wires becomes great enough to heat the wire and to cause it to melt.

If wire melts and breaks in two in the walls of the house it may be the cause of a disastrous fire. Even though no fire results, such a break in the wiring is generally quite expensive to repair. Because of this danger, it is customary to connect in an electrical circuit a fuse which will carry only a limited amount of current without melting. Whenever the amount of current flowing through the circuit becomes greater than the fuse will carry, a wire inside the fuse melts quickly and burns. If a burned-out fuse is replaced by some

other metal—a coin, for instance—which will not melt readily, the wiring some other place may melt when the circuit is overloaded.

If one wire in a circuit is permitted to touch the other wire, without sufficient resistance to the flow of current, enough current flows to melt the wires. Such a condition is called a short circuit. If the insulation of electric appliances burns off, both wires may touch the same metal surface, thus producing a short circuit. If only one of the wires touches the metal, electricity may be carried through a person's body to a radiator or water pipe, which is in contact with the other wire. When current flows through the body, it produces a serious shock and possibly death.

Electric heating pads are unsafe to use where they may become wet. After they are heated for some time the insulation may become cracked, and the crack may be the cause of serious burns or shock. Water heaters which operate by being put into a pan of water are rarely safe to use.

Demonstration. What Is the Principle of the Electric Motor?

What to use: Electromagnet, large needle, cork, dish.

What to do: Connect the electromagnet. Magnetize the needle by rubbing it on the electromagnet, stroking it always in the same direction. Test the needle for magnetism by picking up small iron objects. When it is strongly magnetized, thrust it through the cork, and float it in a dish of water.

Hold the electromagnet some distance above the needle, and make it turn around and around. Change the electromagnet, end for end, and make the needle turn.

If the magnetized needle is removed from the presence of the electromagnet, it points north and south, acting as a compass.

What was observed: Does the electromagnet repel

the needle as well as attract it? Can the push and pull of electricity be used to produce motion?

What was learned: Answer the question at the beginning of the demonstration.

——Things to think about——

Match the following subjects and predicates. Do not write in this book.

Subjects

1. The machine that makes electricity
2. A turbine
3. The electric light
4. About one-half the homes in the United States
5. The shoe of the iron
6. Large power plants
7. A light bulb larger than 75 watts
8. Electromagnets
9. Nichrome wire
10. A fuse wire

Predicates

A. is filled with gas.
B. can produce electricity cheaply.
C. uses heat to produce light.
D. offers high resistance to current.
E. is used to conduct heat.
F. melts to protect the house-wiring.
G. may be turned by water or steam.
H. use electricity.
I. are always used in electric motors.
J. is called a dynamo.

A Review of the Unit

Work is done in overcoming the resistances of gravity and friction. The force of gravity gives weight to objects. Work

is done when a force acts through a distance. The unit of work is the foot-pound. The amount of work done is obtained by multiplying the distance the object has moved by the force used. Friction consumes a great deal of energy which is changed to heat. Friction may be reduced by decreasing the amount of pressure or by making the surfaces smoother.

Better use of energy is accomplished by use of the two fundamental machines: the lever and the inclined plane. Machines which make it possible to use energy are special types of levers, pistons and cylinders, or magnetic devices. Objects in motion are able to do work as long as they continue moving.

Electricity is a convenient source of energy because of its ability to produce heat and magnetism when conducted through wires. Electricity has been made available because of the fact that an electric current is produced in a wire which cuts a magnetic field.

An exercise in thinking

Match the principles and related ideas, according to directions given in the review at the end of Unit I.

List of principles

A. Work is a force acting through a distance.

B. Energy lost in doing work is changed to heat by friction.

C. Energy may be stored in objects at a height, or in objects in motion.

D. A machine must provide a surface against which force may be exerted.

E. A lever is a bar which turns around a point called a fulcrum.

F. An inclined plane is a sloping surface up which objects are moved.

G. The work done by a machine plus the work lost because of friction are equal to the work put into the machine.

H. Machines may be used to change the direction of a force.

I. When a wire cuts a magnetic field a current is produced.

J. There is a magnetic field around every wire carrying a current.

List of related ideas

1. Energy is lost when two objects rub together.
2. A coil carrying a current attracts iron.
3. A nail becomes hot when driven through a board.
4. Water turning a turbine is used for power.
5. A sewing machine runs easier when oil is applied.
6. A flywheel turns between strokes because it has stored energy.
7. No work is done unless an object is moved.
8. Skids are used to load logs on trucks.
9. A piston is used in steam and gasoline engines.
10. A windmill is made up of a number of vanes.
11. Energy is used in dragging a trunk across the floor.
12. We overcome gravity when we lift a pail of water.
13. Electromagnets work only when the current is flowing.
14. All real balances are levers.
15. Screws are used to lift houses.
16. Wheels with teeth cut in their rims are called gear wheels.
17. A man can lift a heavy lifeboat by using a block and tackle.
18. A horse walking on the ground can lift a load into the air.
19. Electricity is made by a dynamo which contains coils and magnets.
20. A baseball bat causes the ball to move rapidly through the air.
21. A doorbell is made up of coils and an iron bar on a spring.

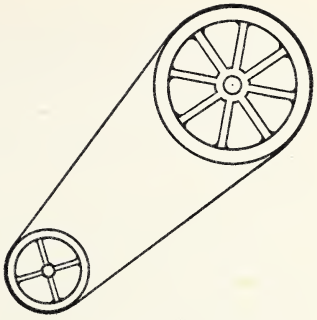
22. The up-and-down motion of a piston is changed to circular motion.

23. Throwing a ball into the air is work.

24. A small movement of the sewing machine treadle moves the needle a considerable distance.

25. A needle is a wedge which pushes the threads apart.

26. A hammer is used to pull nails.



What force keeps the belt from slipping? Which wheel turns faster? Why?

27. It is easier to climb a stair than a ladder.

28. The electric motor does work.

29. Every automobile has a generator of electricity.

30. We pull down to lift a bucket from a well, when using a pulley and rope.

31. Water behind a dam can do work.

32. An automobile jack often contains a screw.

33. A steam engine uses about 10% of the energy in the fuel, and wastes the rest.

An exercise to test yourself

Select the correct word or words needed to complete each of the following sentences. Do not write in this book.

1. When work is done, it must overcome (*a*) heat (*b*) speed (*c*) resistance.

2. Work is measured in (*a*) distance (*b*) foot-pounds (*c*) force.

3. Energy lost when friction is overcome is changed to (*a*) motion (*b*) force (*c*) heat.

4. A bar which turns about a point is a (*a*) wedge (*b*) lever (*c*) gear.

5. A sloping surface used for doing work is (*a*) a lever (*b*) a spring (*c*) an inclined plane.

6. Pistons are used in (*a*) electric motors (*b*) engines (*c*) windmills.

7. Vanes are used in (*a*) turbines (*b*) flywheels (*c*) engines.

8. When like poles are brought together, they (*a*) attract (*b*) become heated (*c*) repel.

9. The electric circuit of a house is protected by the (*a*) wires (*b*) electromagnets (*c*) fuses.

10 Electricity is made by a (*a*) motor (*b*) dynamo (*c*) turbine.

11. Heat is produced when electricity encounters (*a*) friction (*b*) wiring (*c*) resistance.

12. An electric motor always contains (*a*) a turbine (*b*) electromagnets (*c*) resistance wire.

Some good books to read

Book of Popular Science, Grolier Society

Brown, H. T., *Manual of Mechanical Movements*

Byrd, Richard E., *Skyward*

The Champion Cyclopedia for Young Folks

Collins, A. F., *Aviation and All About It*

Collins, A. F., *Bird's-Eye View of Invention*

Collins, A. F., *The Experimental Mechanic*

Compton's Pictured Encyclopedia

Huey, Edward B., *What Makes the Wheels Go Round?*

Klemin, Alexander, *First Book in Aviation*

Lake, C. H. and Unself, G. P., *A Brief Course in Physics*

Lunt, J. R., *Everyday Electricity*

Meister, M., *Energy and Power*

Mott-Smith, M. C., *The Story of Energy*

Polak, Janet, *This Physical World*

Whitman, W. T., *Household Physics*

Courtesy Northern Pacific Railway

UNIT SIX-A
(for Special Reading)
OF WHAT USE IS THE AIR AROUND US?

We have observed things living on the ground, in water, and in the air. Have you ever thought what might happen to them if there were no air? We often see birds flying high in the sky. Do you know how high they can go? What supports them? Yes, it is air. But what is air? And how much air is there?

Air may be found everywhere on the surface of the earth, high above the tallest mountains, deep in the earth and oceans. It carries moisture which may fall as rain or snow. Air brings storms and is the substance of winds. It keeps us warm by carrying heat from one place to another. Air is considered to be part of the earth. It has a special name—the atmosphere [ăt′mŏs·fēr], which means the vapor or breath of earth. The atmosphere is the outer covering of the earth.

What does air do for us? Air makes basketballs bounce and eases the bumps on the rough roads under our automobile tires. It cushions our heads when it is held by feathers in pillows. Air pushes our sailboats about the lakes, holds the airplanes and birds in flight, and snaps the branches of trees in storms.

Air gets energy [ĕn′ẽr·jĭ, ability to do work] as it is heated by the sun, the source of all heat upon the earth. Air containing more energy tends to move faster and occupies more space. This light air becomes as strong as a giant when moved by the energy it gets from the sun.

Air does its everyday work in the kitchen in making whipped cream and eggs fluffy, and in filling the bubbles in soapsuds for washing dishes. Air picks up the dirt from the rugs and dries the clothes on washday. Air moves through our stoves and furnaces, making the fires burn brightly. Air carries away the smoke and gases from the chimneys. Air helps to destroy the metals we may leave exposed. It removes dead material by helping to cause it to decay.

Can you explain how the air is able to do these things? You will find the answers to your questions in the problems in this unit.

Courtesy U. S. Army Air Corps

This parachute jumper is riding on air to avoid crashing to the earth. Because air is light, a large parachute must be used to catch enough air to hold up the man's weight.

1. Is air a real substance?

Can you see air? Can you taste or smell air? How can you know that air is real? When you study science it is not enough to assume that air is real because you think it is. Proof is always necessary. How can you prove that air is real and not imaginary? In science we make use of our senses in observing and studying real things. However, some things cannot be studied directly by the senses. We must learn about them by observing what they do.

All real things are made of matter. Matter has weight and takes up space. Because matter is real, it can be measured. Can we prove that air is a form of matter?

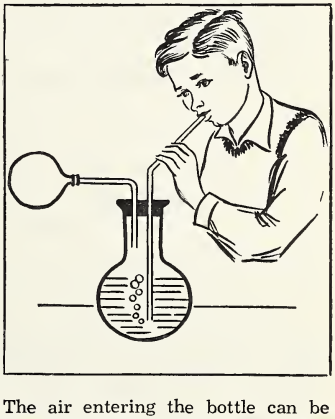
What do our senses tell us about air? Air has no noticeable taste. You cannot sense any difference in your mouth because of having air in it. We say pure air has no odor because its odor is familiar to us. At times we say that air smells foul or fresh, but these odors come from other things, such as decaying vegetation or from growing plants. Air can carry odors.

Under ordinary circumstances we cannot see air. Sometimes we can see waves in the air over a hot stove or above a distant pavement. We can see dust carried by moving air, and we can see boats, kites, and windmills move when the wind blows. Usually we can feel air to some extent. If you fill your lungs with air and blow against your hand, you can

feel the pressure of the air. If air is blown through the teeth, it makes a hissing noise. We hear a bus horn which is operated by air. So we are able to hear the effects of air.

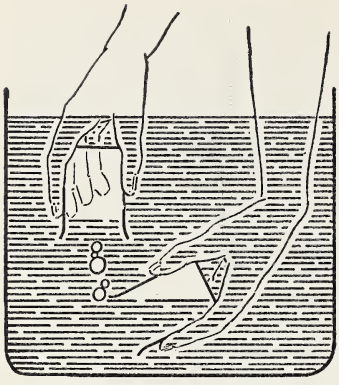
Does air occupy space? We can test by experiment whether air can occupy space. To show that there is air in an empty glass, you can turn a glass upside down and push it under water. Instead of filling the glass, the water enters only a small part of the way. Air inside the glass fills the remaining space so that there is no room for the water to enter.

It is rather easy to see the effects of air as it is blown into a balloon. Suppose a bottle is partly filled with water, as shown in the drawing. A glass tube long enough to reach the bottom of the bottle is put into a stopper. A short tube is used as an outlet. The balloon is fastened over the end of the short tube with a rubber band. You can blow through the long tube and see air bubbles rise through the water. The balloon is blown up, showing that air entered it. This way of increasing the size of the balloon shows that air is really being used to fill the space in the balloon.



The air entering the bottle can be observed. What happens after the balloon is blown up, when you stop blowing? How do you know that air is real? Do you know that it can exert force?

Blowing soap bubbles is another way of showing that air takes up space. Soap bubbles can be blown by using the air from a tire pump. If you were to blow the soap bubbles with your breath and think about it as the scientist does, you might suspect that the bubbles were filled with a material produced in the body. By using the pump, we know that the bubbles are



Because air is a real substance, it can be poured from one container to another. Why is it difficult to pour air without putting the containers under water?

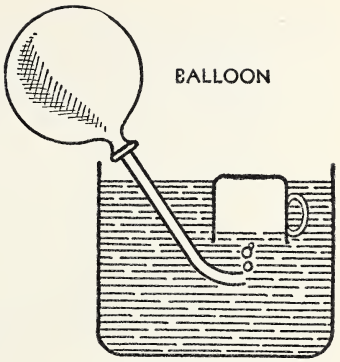
filled with air. Can you blow lasting bubbles in water which does not contain soap?

Air not only occupies space, but it can be poured from one container to another. To show this, we need two water glasses and a large container filled with water. If we fill one glass with water in the jar and raise it mouth downward so that it is partly out of the water, the water will stay in the glass. Another empty glass may be pushed mouth downward to the bottom of the jar. By carefully tipping the lower glass, the bubbles can be released under the mouth of the first glass so that the air flowing upward will push the water out of the upper glass. Could an imaginary substance be poured in such a way?

Where is air found? There is air everywhere near the surface of the earth. Airplanes have risen more than 10 miles into the air, which is proof that air extends to this level. Astronomers [ăs·trŏn′ō·mẽrz, people who study the science of the sun, moon, planets, and stars] tell us that air probably extends more than 500 miles high. Have you seen the Northern Lights race across the sky in bright bands of colored light? The Northern Lights depend upon electricity acting upon the air to produce the beautiful glow we see. Thus we know that air must extend at least that high. Meteors, or "shooting stars," begin to burn about 90 miles above the earth. How high has man been able to go?

Air is found in all fairly dry soil and in the rocks of the earth for a short distance below the surface. It is easy to prove that there is air in the soil. Fill a glass with dry soil.

Press it down firmly and pour water over it, covering the soil completely. You can see bubbles of air rise from the soil. In a similar manner you can prove that there is air in slices of bread, in sponges, and in cloth. All porous [pō′-rŭs, full of pores or holes] materials contain air.



This drawing shows you how to arrange the materials to do the experiment. How much air can you crowd into a balloon?

That air is found in water may be shown by drawing a glassful from the faucet and letting it stand to get warm. Bubbles will form around the sides of the glass. Try this with some water that has been boiled and cooled. Boiling drives the air out of the water. Would you boil water to use in a fish bowl? Since blood is principally water, would you expect it to contain air? Air is found in all living things.

Can air be measured? The best way to prove that air can be measured is to experiment. Can you think of a way of experimenting to find out if air can be measured by using a measuring cup, a balloon, a jar of water, and some glass tubing?

Demonstration. Can Air Be Measured?

What to use: Balloon, glass tubing, rubber band, glass measuring cup or cylinder, battery jar or pail, and thermometer.

What to do: With a rubber band, fasten the balloon on the end of a glass tube about four inches long. Blow up the balloon and tie it so that the air cannot escape. Fill the jar with water. Fill the cup or cylinder with water by inverting it in the jar. While one person holds the measure, let another put the end of the glass tube under the cup, and permit the air from the balloon

to escape slowly into the cup until the water runs from the cup. Stop the air as soon as the cup is filled. Let this air escape by tipping over the measure. Refill the cup with water and repeat, filling it with air until the balloon is completely empty. Squeeze out all the air from the balloon.

What was observed: How many measures of air were in the balloon?

What was learned: Select the correct conclusion.

(*a*) Air can be measured under water with a measuring cup or cylinder.

(*b*) The air in the balloon always takes up exactly the same amount of space as the air in the measure.

(*c*) Measuring air proves that we can measure things even though they cannot be felt or seen.

——Things to think about——

Write the numbers from 1 to 8 on a piece of paper or in your notebook. Opposite each number write the letter before the word or group of words which best completes the sentence.

1. It is difficult to fill a narrow-necked bottle under the faucet because the (*a*) air is too heavy for the water to push out (*b*) neck of the bottle is too small for the drops of water (*c*) air in the bottle cannot get out because of the stream of water.

2. Pure air is (*a*) odorless and tasteless (*b*) without weight or pressure (*c*) found everywhere in the world.

3. Things which really exist (*a*) are quite heavy (*b*) occupy space (*c*) are always visible.

4. If a tumbler held upside down is pushed under the water, the water will rise into the tumbler only a little way because (*a*) the air keeps the water out (*b*) water will not run up hill (*c*) the tumbler is not low enough.

5. Air is not found in (*a*) boiled water (*b*) pond water (*c*) soil (*d*) open bottles.

6. Blowing soap bubbles is one way of showing that (*a*) the bubbles are filled with a material produced in the body

(*b*) air takes up space (*c*) lasting bubbles cannot be made.

7. Northern Lights are caused by (*a*) rainbows (*b*) the light from the moon (*c*) electricity acting upon the air.

8. Water animals and fish get air (*a*) by coming to the surface of the water (*b*) from the food they eat (*c*) from the water.

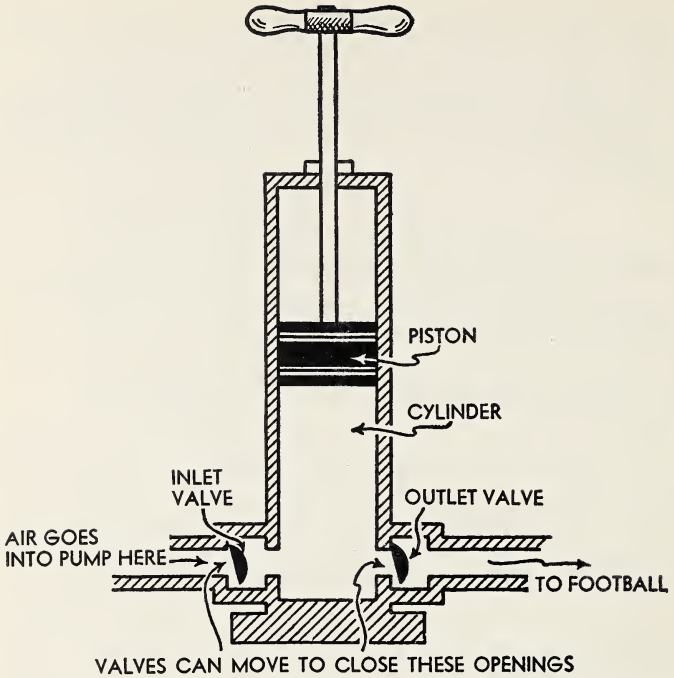
——Science activity for fun——

Read through this problem carefully, and find experiments which you can do at home. Do them. A good scientist tests as many things as he can for himself.

2. Does air have weight and exert pressure?

Two boys made a dirigible [dĭr'ĭ·jĭ·b'l] balloon to enter in a model aircraft show. They made the framework of balsa wood and covered it with cellophane so that the dirigible would be light in weight. They had not found a way to make it float. One boy suggested that they use a rubber balloon inside the framework to hold air. He said that since air is light in weight, pumping more air into the balloon would make it lighter. The second boy did not agree with him. He said that the more air they pumped into the balloon, the heavier it would become. Which boy was right? Since the balloon could expand only until it filled the frame, what effect would adding air have other than changing the weight? To answer these questions, let us experiment as scientists do when they wish to solve a problem.

Does air have weight? Suppose you were to tie a piece of string in the middle of a strong, lightweight stick and hang it from a support so that it would not touch anything. To one end of the stick attach a football which has been pumped as full of air as it will hold. On the other end of the stick attach a strong paper sack or a light pail. Have someone hold the football in place while you put sand into the container until it just balances the football. Then let the air escape from the ball. Which end of the stick do you think will go



Can you explain just how the air pump works? When the piston is pushed down, which valve is closed by the air? Which valve opens when the piston is pulled up? What pushes on the valves of the pump?

down? Was the first boy right? Pumping air into the balloon, then, would have made it too heavy to float.

How does the air pump work? A simple air pump is made of four parts: the cylinder [sĭl′ĭn·dĕr, a tube], usually made of metal; the piston, which is a sliding part made of metal and leather to fit the tube; and two valves, located near one end of the tube. This end of the cylinder is tightly sealed. The valves are two pieces of metal or rubber which operate by pressure of the air and close the inlet and the outlet tube located near the closed end of the cylinder.

When the piston is moved up by pulling upward on the

handle, the inlet valve opens and air moves past it into the cylinder. When the piston is pushed down, the pressure closes the inlet valve and the air is forced out through the outlet valve. If the outlet tube is attached to a container such as a flask or a football, the air which was pushed into it will press back on the outlet valve to keep it closed. On the second upward stroke, the inlet valve will be opened by the pressure of the outside air so that more air will enter into the cylinder.

Edgerton, Germeshausen and Grier photo

The elastic football is deeply dented by the foot of the kicker. Because of the pressure of air in the ball, it springs quickly back to its original shape. This photograph was taken at 1/100,000 of a second. How fast does your camera take a picture?

To understand how the valves are opened and closed, imagine two boys, one inside and one outside a room, pushing on a door that opens outward. The door is closed when the pressure on the outside is greater, but is opened when the pressure on the inside is greater.

Why is a football pumped up? You may have seen a toy football stuffed with cloth or paper instead of being filled with air. If you pinch it, it loses its shape. Air helps a football keep its correct shape. If you try to throw or kick a stuffed football, you discover that it does not travel fast. Besides being heavy, the ball feels awkward because it is not firm. It hardly bounces at all. Air exerts pressure, or pushes, on all parts of the inside of the football with equal force, causing the ball to be uniformly hard in all places.

Another reason for pumping up a football is that air is highly elastic [ē·lăs'tĭk]. A material is elastic if it will recover its original size and shape after being bent or twisted. Rubber is elastic, but not as elastic as steel, since rubber

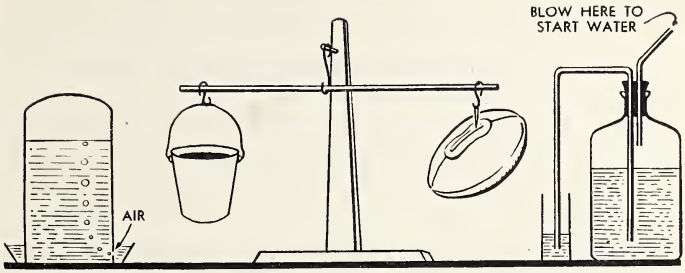
Courtesy H. D. Hudson Mfg. Co.

The water in the fountain is prevented from running out all at once by the pressure of the air. Air can hold water in a fountain more than 30 feet high. How high is this fountain?

never quite recovers its original position. When a football is kicked, the foot makes a big dent in the side of the ball. Almost immediately the air pushes the leather back into place and gives the ball a liveliness that it would not have if it were not filled with the elastic air.

How does air exert pressure in a balloon? When air is blown into a football, the leather jacket keeps the ball from expanding. More air is crowded in with each stroke of the pump. We say that such air is compressed [kŏm·prĕst′, squeezed or pressed into a smaller space]. When blown into a balloon, air is compressed to some extent, but not so much as it is when pumped into a football. The balloon has no cover on the outside to keep it from stretching, and as air is forced into it, it becomes larger. The pressure of the air inside the balloon stretches the rubber because the space in which air is enclosed may change size in a balloon. A given amount of air is under less pressure in a small balloon than it is in a football.

How is air used in tires? The automobile tire is filled with air in much the same way as is a football. The inner tube



The water fountain (*left*) uses the weight of the air to hold water in the container. The simple balance (*center*) can be used to show that air has weight. The water bottle (*right*) should be set up in your home laboratory if you have no running water. Germs on the mouthpiece may be killed by heating it with a flame. Let it cool before using!

compares with the rubber bladder inside the leather cover of the ball. The pressure of the air in the tires supports a load of hundreds of pounds on each wheel. Because it is elastic, air eases the bumps of the tire striking the road. The pressure of air in a tire is two or more times as great as ordinary air pressure.

How can water be kept in an inverted jar? A water fountain used for chickens makes use of the weight of the air to keep the water from running too rapidly from the container. The fountain is made up of two parts: an inverted can or jar, holding the water supply, and a pan from which the chickens drink. To set up the fountain, the can is filled with water, and the pan is placed over the open top of the can. The can is then turned upside down. From a small opening in the can the water runs into the pan. When the water in the pan becomes deep enough to cover the opening, no more water can run out because no air can enter the can. The weight of the air pressing down on the water in the pan must be equal to the weight of the water inside the can plus the weight of the air confined above the water.

As the chickens drink the water, or as it evaporates, the opening is uncovered and air bubbles rise in the can, allow-

ing more water to run into the pan. In this kind of fountain the water supply is kept clean, and small chickens do not drown in the water as they might in a large open pan of water.

How can a supply of water be stored in the classroom? In some classrooms there is no source of running water, and it becomes necessary to store a supply of water for experiments. Often distilled or purified water is needed. In either case, it is easy to set up a container of water so that the water can be drawn from it at any time. Follow the directions in the demonstration, and set up a container like that shown to the right in the diagram on page 77.

Demonstration. How Does Air Control the Flow of Water?

What to use: Large bottle filled with water, stopper, glass tubes, rubber tubes, a clamp or spring clothespin, beaker.

What to do: Put glass tubes into the stopper as shown in the diagram, and place the stopper in the bottle. Attach the rubber tube to the longer glass tube. Put the end of the rubber tube into the beaker and blow on the open end of the shorter tube. When the water has run into the beaker, the flow may be stopped by using the clamp or clothespin on the rubber tube. Stop the flow of water before you stop blowing on the tube. When the clamp is open, the water will flow without blowing into the bottle, if the end of the rubber tube is left below the surface of the water in the bottle. The weight of the air entering the open glass tube is sufficient to push the water out of the bottle, if the rubber tube is placed low enough for the water to run out easily.

What was observed: Describe what happened when air was blown into the bottle.

What was learned: Select the correct conclusion.

(*a*) The weight of the air can be used to move water over an obstacle.

(*b*) Water naturally runs uphill.

(*c*) Air is sucked from the bottle to move the water.

——Things to think about——

Write the numbers from 1 to 8 on a piece of paper or in your notebook. Opposite each number write the letter before the word or group of words which best completes the sentence.

1. Air is useful in a football because it (*a*) makes the ball so heavy that it will travel a long way (*b*) makes the ball so light that it almost floats in the air (*c*) makes the ball elastic and firm.

2. In an air pump the valve moves (*a*) away from the higher and toward the lower pressure (*b*) back and forth because it is worked by the handle (*c*) whichever way works best.

3. Air which is forced into a closed container is said to be (*a*) expanded (*b*) compressed (*c*) balanced.

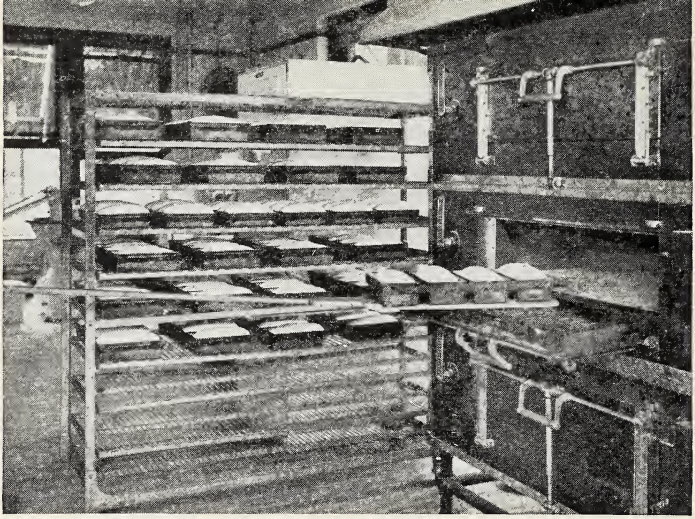
4. It can be shown that air exerts pressure because it (*a*) has no weight (*b*) will stretch rubber in a balloon (*c*) feels warm above a stove.

5. We know that air has weight, because (*a*) a balloon will sink in water (*b*) we can feel it pressing on us (*c*) it can be weighed in a closed container.

6. Air is used in tires because it is (*a*) hard (*b*) heavy (*c*) elastic.

7. The correct pressure for tires is (*a*) slightly less than ordinary air pressure (*b*) two or more times as great as ordinary air pressure (*c*) the same as ordinary air pressure.

8. The cylinder of an air pump is (*a*) another name for a valve (*b*) the sliding part (*c*) a tube usually made of metal.



Norton and Peel photo

When bread is baked in the oven, it rises because the gas held in the dough expands. Note that the loaves are placed on a big wooden paddle and pushed into the oven.

——Science activities for fun——

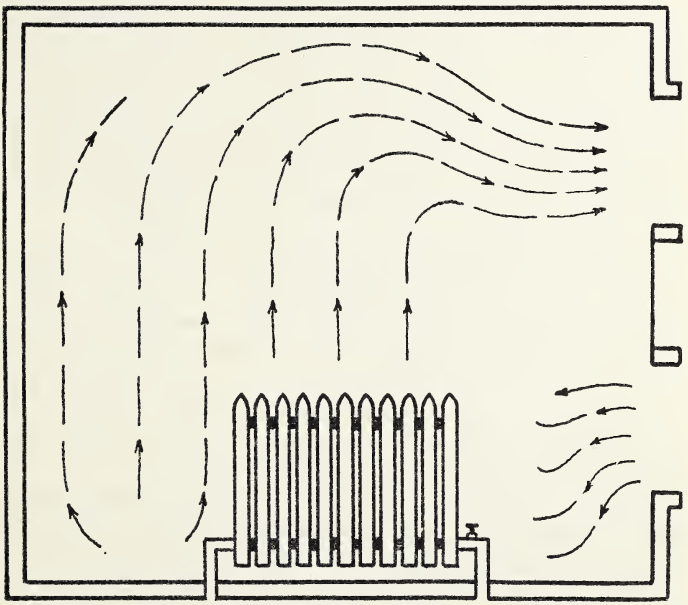
1. Weigh air in a football as described in the problem.
2. Take a bicycle air pump apart, and see if you can discover the use of its parts. There will be no valve on the outlet because the tire has a valve. The inlet valve is a piece of leather on the piston. Explain how it works.

3. What do we gain from heated air?

Heated air may remind you of the hot days of midsummer or the cozy warmth of your home during a raging winter storm. Although keeping cool in summer and keeping warm in winter are important problems, we will understand them better if we discover what changes air undergoes when it is heated. When we have studied these changes, we will be more capable of adjusting ourselves to extremes in temperature. You may have noticed that your bicycle tires become very hard during extremely hot weather and that often they

have to be pumped up during a cold period immediately following. Perhaps you thought the air had escaped. If so, did you wonder why?

Does heating air change its volume? Let us attach a balloon to the open neck of a flask and apply heat to the flask. As the air in the flask is heated, the balloon is blown up. The air must have expanded. When the air in the bottle expands, some of it goes into the balloon; so there is actually less air in the bottle than there was at the beginning of the experiment. The air remaining in the bottle weighs less after it has been heated. Usually some air is lost in this experiment by leakage around the neck of the flask. As the flask cools, the air contracts (takes up less room), and the outer air may push the balloon into the bottle.



Air circulates in a room because of the difference in the weight of cold and warm air. Can you tell from this diagram whether the outdoor or indoor air is colder?

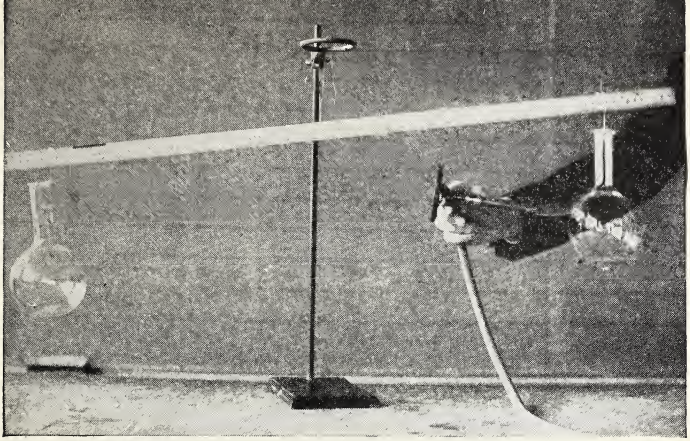
Suppose the flask had been tightly closed so that no air could escape when it was heated. What do you think would have happened? The volume of air could not change, but the air would still tend to expand. It would push against the sides of the container with greater force and probably would blow out the stopper or break the flask. Thus we see that by heating, air can be changed in one of two ways. First, the volume may increase and the weight may decrease. Second, the volume and weight may remain the same but the pressure will increase. This requires that the container must be closed. Since your bicycle tires cannot expand because of the cord inside the rubber, the inside pressure increases slightly and the tire becomes harder. Can you explain why more air might be put into a tire on a cold day?

Does heating the air cause it to move? If you place several thermometers in a closed, heated room on a very cold day, you may be surprised at the difference in temperature in different parts of the room. A thermometer placed about halfway up on the wall may read 68 degrees. A thermometer placed near the ceiling may read 85 degrees. One near the floor may read only 55 degrees. A thermometer placed below an ice-covered window may read as low as 45 degrees, while one placed above the window may read 70 degrees.

In measuring room temperature, you notice that the room is colder near the floor and below the cold window. Since cooling air causes it to contract, a given volume of cold air weighs more than it would if it were warm. The heavy cold air flows to the floor. Cooling air near a window makes a down current, while warming air by a radiator makes an up current. You can test this by using a smoking candle. (*Be careful not to burn anything with the candle.*)

Another way to prove that cold air is heavier than warm air is to balance two flasks of the same volume on a good balance or on a balanced meter stick. If one flask is heated with a flame, the air in it expands and enough escapes to make the flask weigh less. It rises as the heavier flask sinks.

Often on cold days it is useful to have an electric fan in



These two large flasks were balanced at the same temperature. Heating one of the flasks causes it to rise. Can you explain what makes the heated flask lighter in weight than the cold flask?

the living room to keep the warm and cold air mixed. Modern ventilating systems use fans to keep the air from forming layers of cold and warm air. This same movement of air occurs outdoors as it is heated or cooled in moving over the earth. Such temperature differences are responsible for our winds, rainfall, and ventilation, and for keeping the air pure.

How are winds related to this air movement? The chief difference between the movement of air in a room and out of doors is the size of space in which the air moves. Of course the heating out of doors is done by the sun.

Where the land is warm, the air is heated and becomes lighter. Lighter air is pushed upward by the heavy colder air. Have you seen the small whirlwinds filled with dust on a hot summer day? They are small movements caused by very hot air close to the ground suddenly breaking through the layer of colder air above. If these small whirlwinds occur in dry places, they pick up dust and carry it long distances. Such whirls may extend into the air several hundred feet, and travel more than a mile along the ground.

The larger winds of the world work on the same general plan as do smaller winds. The air is always being heated or cooled. The cooled air becomes heavy, and finally exerts

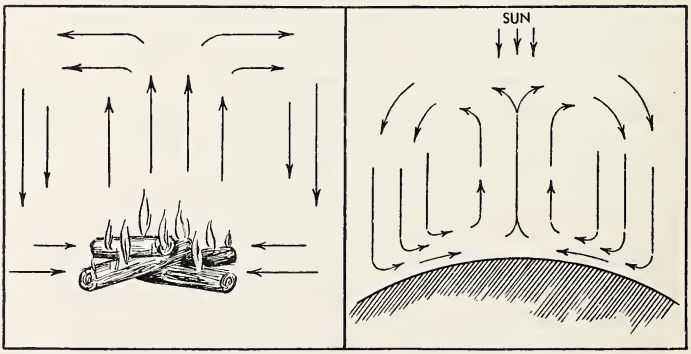
enough pressure to cause the warm air to be pushed up.

The winds carry water to us from the ocean, and keep us from being too hot or too cold. The wind system was not arranged for our convenience, however. It was here long before man learned its value to him and began to fit himself to take advantage of the good things brought by the wind, and to protect himself against the unpleasant storms which winds bring. A scientist always remembers that man and all living things have been forced over hundreds of thousands of years to fit into the world, and that the world has not been changed to suit his convenience.

Demonstration. How Is the Volume of Air Changed by Heating?

What to use: Dry flask (250 cc), balloon, burner.

What to do: Squeeze the air from the balloon as completely as possible, and slip the open end of the balloon over the mouth of the flask. Carefully heat the flask, observing the balloon. A Pyrex flask can be made quite hot without danger of breaking. Then permit the flask to cool until it can be held comfortably in the hands. Continue cooling the flask as much



The circulation of heated and cooled air outdoors is the same as indoors, and the same whether heat comes from a fire or from the sun. The part of the earth where the sun is directly overhead is hottest.

as possible by using either cold water or a piece of ice.

What was observed: How much change can you make in the size of the balloon?

What was learned: Select the correct conclusion.

(*a*) Heating the flask drove the moisture out of the air into the balloon.

(*b*) Heating the flask caused the balloon to expand because the balloon got hot.

(*c*) Heating the flask and later cooling it showed that air expands when heated and contracts when cooled.

——Things to think about——

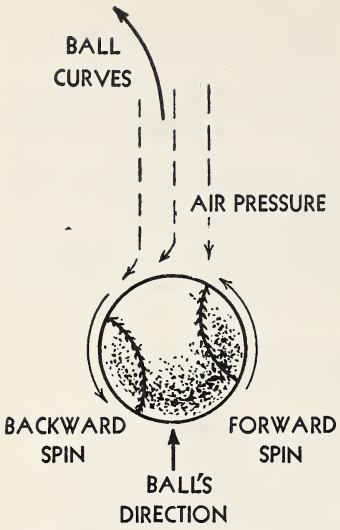
Write the numbers from 1 to 7 on a piece of paper or in your notebook. Complete the following sentences to make true statements. Opposite each number write the word needed to complete the sentence.

When air is heated it is forced to rise because it has less —1—. When air is heated in a closed container the —2— is increased. The temperature of a room is usually lowest near the —3—. When two flasks are balanced, and one is heated, the experiment proves that hot air has less —4— than does an equal volume of cold air. Air pressure is highest where the temperature of the air is —5—. Moving air is called —6—. Pressure of tires goes down when the temperature is —7—.

——Science activities for fun——

1. Mix flour, baking powder, and water to form a fairly stiff dough. Use one teaspoon of baking powder and one cup of flour. Heat the dough to see how much it expands.

2. *How to put an egg into a bottle.* Peel a hard-boiled egg. Drop some burning paper into a milk bottle, and place the egg on the mouth of the bottle, small end down. Why does the egg go into the bottle?



The curving flight of a ball is caused by air pressure. The spinning motion increases the pressure on one side and reduces it on the other. A tennis ball curves readily, a baseball hardly at all.

4. How do changes in air pressure affect us?

When you learn that warm air is lighter per unit of volume than cold air, you may wonder why we do not feel a greater weight on our bodies on cold days than on warm days. There are two reasons why you do not notice differences in pressure. The differences are not very great from day to day, and the body is able to adjust itself by changes of pressure inside the body. About the only time you are likely to notice differences in air pressure is when you go suddenly to a higher elevation. Then your ears "pop," and your breath comes with greater difficulty.

How does air exert pressure? The air rests upon the surface of the earth, just as a stone rests upon it. The air, being less dense than the stone, exerts less pressure for a certain volume. But there is a great deal of air above the earth. This large amount of air is heavy enough to exert a pressure of almost 15 pounds on every square inch of the earth's surface.

How do we measure air pressure? If you want to see how strong you are, you might find some surface on which you could push. You could measure your strength by seeing how heavy an object you could move. To measure air pressure, we use an instrument called a barometer [bȧ·rŏm′ ĕ·tẽr]. It is easy to make a barometer. All you need is a glass tube a little more than 30 inches long, closed at one

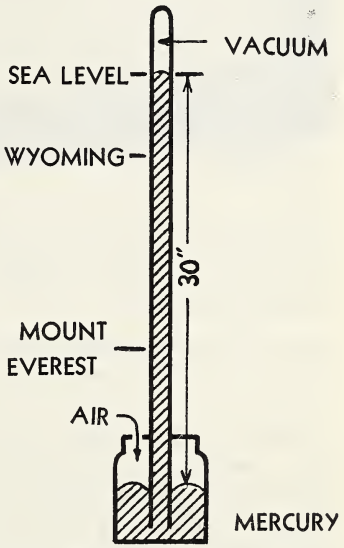
end, a dish, and a pound of mercury. Mercury is a shiny liquid metal sometimes called quicksilver.

The tube is filled with mercury by use of a dropper or a funnel connected by a rubber tube to the glass tube. When the tube is full, and all the air bubbles are shaken out, the rest of the mercury is poured into the dish. Then the finger is used to seal the open end of the tube, and the tube is turned upside down. The open end is placed beneath the mercury in the dish.

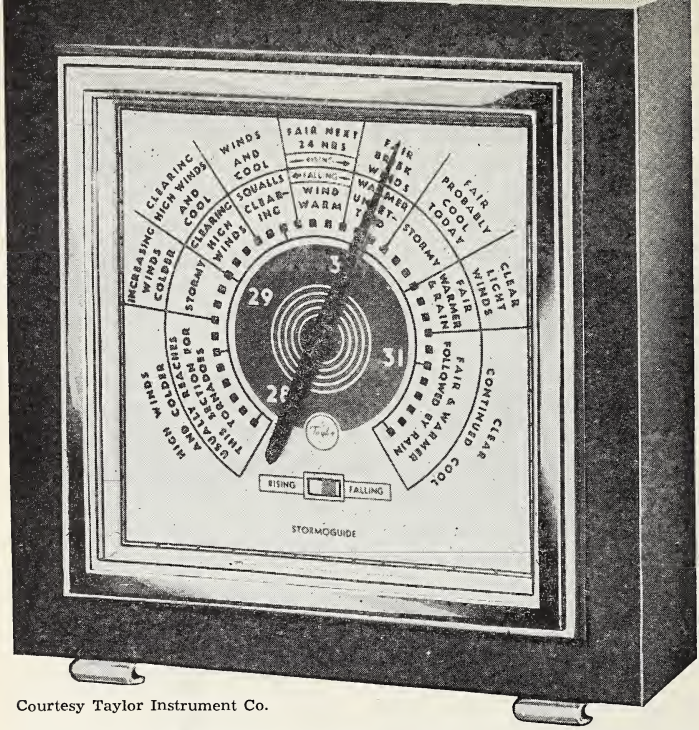
Some of the mercury runs from the tube, but the pressure of the air holds most of it in the tube. The air presses upon the mercury in the dish, but there is no air in the tube to press upon the mercury in the tube. The result is that we find the mercury soon reaches a height of about 30 inches, at sea level, and remains there.

This experiment was first done by an Italian scientist, Galileo [găl·ĭ·lē′ō]. He used water in his barometer. Water is lighter than mercury, which made it necessary for Galileo to make his barometer 34 feet high. One of his pupils, Torricelli [tôr-rē·chĕl′lē], used mercury instead of water.

Another kind of barometer, which is called the storm guide, contains a springy, hollow metal disk. The air pressing upon the sides of the disk forces the disk to become thinner as the pressure becomes greater. When the sides of the disk move, a needle attached to them is



With simple apparatus you can make a barometer. The height of the column of mercury is shown for three different locations. Why are there differences in air pressure?



Courtesy Taylor Instrument Co.

The storm guide indicates the relation between the air pressure and the weather. The numbers on the dial indicate air pressure in inches of mercury; the inner circle tells the kind of weather brought by falling air pressure; the outer circle gives the kind of weather brought by rising air pressure.

turned. This storm guide does not show the pressure in inches as the mercury barometer does, but indicates the probable weather.

How is air pressure related to weather? As you already know, warm air is lighter than cold air. We can measure these differences in weight with a barometer. Warm air in one place may be able to support only 29½ inches of mercury, when cold air elsewhere may support 30½ inches of mercury in the barometer. Usually the difference in pressure is not more than an inch of mercury.

Even though the differences in pressure are small, cold air masses force the warm air masses to move aside, and winds result. It has been found that we usually have rainy

or cloudy weather when the air pressure is low, and that we usually have clear weather when the air pressure is high.

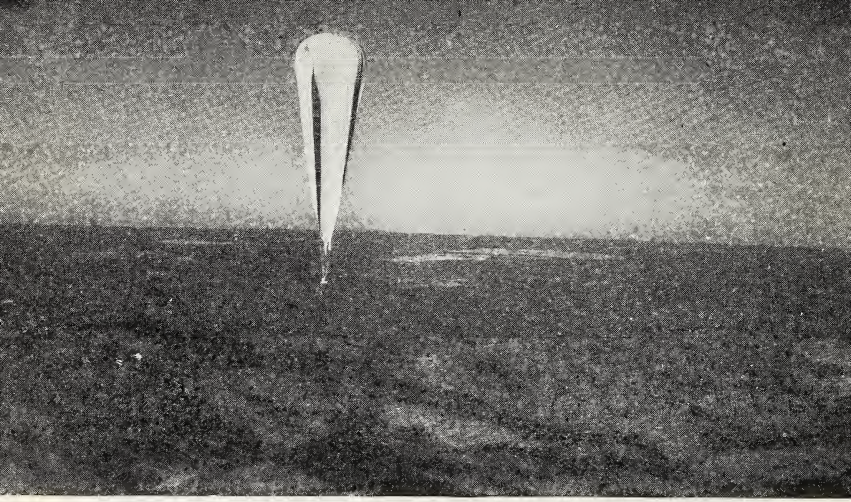
Does air pressure change as we go to higher levels? The weight of the upper air tends to press the air together near the earth. As we go higher, there is less pressure, since the upper air is thinner than the lower air. If we were to draw lines on a chart of the atmosphere at levels where the quantity of air was the same, we would see that it would be necessary to go higher and higher to include the same weight of air. The pressure of the air more than 20 miles high has been measured by means of free balloons carrying barometers which make permanent records. Since the air is thin, the pressure is very small. At 20 miles it will support a column of mercury only one-fourth of an inch high.

Scientists have gone up into the upper air in specially constructed balloons. That part of the air above seven miles is called the stratosphere [strā′tō·sfēr]. Here there is no dust or water vapor, and there are no clouds. The scientists wished to measure the air pressure, the temperature, and the amount of electricity in the air. They also wished to take pictures. So they had to design special balloons.

A stratosphere balloon is made of two parts. One part is a large bag made of specially treated cloth, and filled with hydrogen [hī′drō·jĕn, a very light gas]. The other part of the balloon is a sealed metal room in which the men and scientific instruments are carried. There is not enough air in the stratosphere for men to breathe; so they take with them the necessary substances to make their own air.

As the balloon starts its rise from the earth, it hangs limp and seems somewhat empty. When it rises higher, the pressure of the air is less, and the gas bag becomes more round. At a height of several miles the bag is round like a ball, and stretches so much that it is necessary for the men to open a valve to let out some of the gas. Otherwise, the bag might burst.

Can we tell how high we are by means of a barometer? At your level the barometer reading varies from day to day with the changes in temperature, the amount of water vapor



Courtesy U. S. Army Air Corps

Judging from the shape of the stratosphere balloon, is it near the earth or high in the air? This photograph was taken from an airplane.

in the air, and the movement of the wind. Over a long period of time an average reading can be made. By comparing this with the average reading at sea level, it is possible to determine your height above sea level. If you live in Vancouver, the average barometer reading is about 30 inches. If you live in Calgary, the barometer reading is about 26 inches.

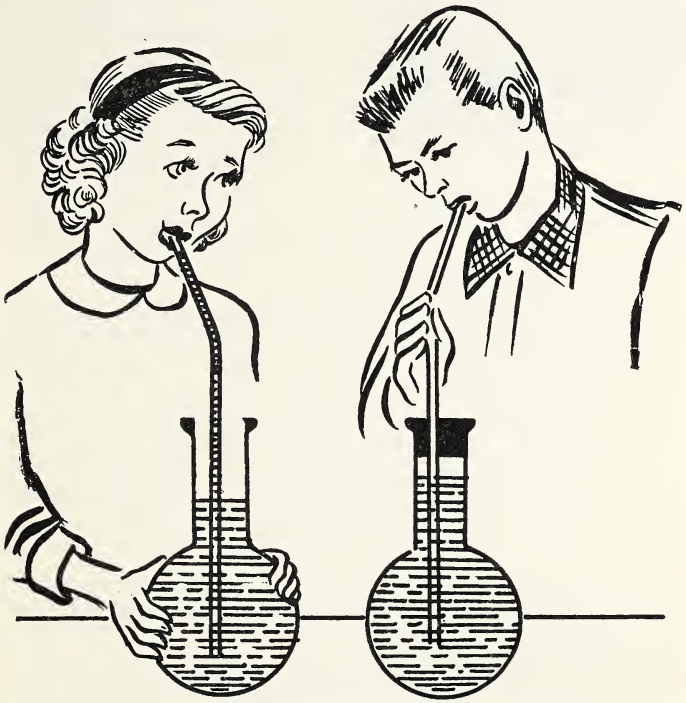
The average air pressure at a place 900 feet above sea level causes the barometer to read 29 inches of mercury. Remember, the higher you go, the less the air pressure is. The table below gives an idea of how the pressure varies.

ALTITUDE	AIR PRESSURE IN INCHES OF MERCURY
Sea level	30
900 feet	29
1800 feet	28
2700 feet	27
3700 feet	26
4800 feet	25
5800 feet	24
7000 feet	23
18,500 feet (3½ miles)	15

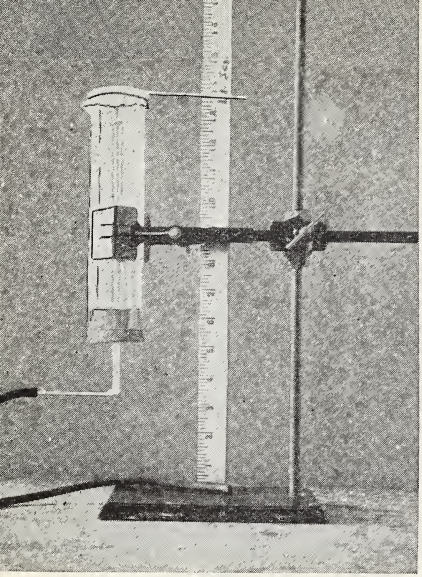
Since the city of Calgary is about 3500 feet above sea level, you can see why the barometer reading there differs from the reading in Vancouver.

Aviators make use of an altimeter [ăl·tĭm′ė̇·tēr] to tell how high they are. It is very much like a storm guide, except that its dial is marked in thousands of feet. It can be set at zero for any elevation so that the pilot can tell how high he is above the ground where the flight began.

Will air pressure move water? When you suck pop or any other liquid through a straw, you reduce the air pres-



Why is the boy getting nothing to drink? What force causes the water to rise in the girl's mouth? What would happen if the boy should loosen the stopper of his bottle?



This photograph shows you how to set up the apparatus for the demonstration.

sure in your mouth. Then the weight of the air pressing on the liquid pushes it up into the straw and into your mouth. If you put a glass tube through a rubber stopper, and fit it into a bottle of water, it is impossible to withdraw the water because the stopper shuts out the air.

Demonstration. How Does Air Pressure Move a Pointer?

What to use: Argand lamp chimney, Number 10 one-hole stopper to fit, ring stand and clamp, glass and rubber tubing, rubber dam or part of a small balloon, rubber band, glue, meter stick.

What to do: Arrange the apparatus as shown in the photograph. Fasten the small stick to the rubber dam with a drop of glue. Blow air into the lamp chimney through the tube, and observe the pointer. Withdraw the air from the lamp chimney. Observe the pointer.

What was observed: Which way does the pointer move as air pressure below the rubber dam is increased? Decreased? What kind of barometer is similar to the apparatus?

What was learned: Select the correct conclusion.

(*a*) Air pressure is strong enough to make the rubber dam float higher.

(*b*) Changing the air pressure upon an elastic surface can be used to move a pointer.

(*c*) Moisture from the breath changes the position of the pointer just as approaching rain does.

——Things to think about——

Write the numbers from 1 to 8 on a piece of paper or in your notebook. Opposite each number write the letter before the word or group of words which best completes the sentence.

1. The thing in this list which does not change ordinary air pressure is (*a*) differences in temperature (*b*) elevation (*c*) pressure of the blood (*d*) sucking pop through a straw.
2. A storm guide is really (*a*) a barometer (*b*) a pressure gauge (*c*) an air pump (*d*) a thermometer.
3. Many barometers contain (*a*) water (*b*) alcohol (*c*) mercury (*d*) moisture.
4. Air pressure is lowest (*a*) in Edmonton (*b*) in Victoria (*c*) at the top of Mount Robson (*d*) in Calgary.
5. Wind is the result of (*a*) differences in temperature of masses of air (*b*) a change in weather (*c*) the depth of the layer of air around the earth.
6. Dust, water vapor, and clouds are found in (*a*) the layers of air above seven miles (*b*) the air within seven miles of the earth (*c*) the air only when the temperature is low.
7. The instrument used for measuring air pressure is called a (*a*) barometer (*b*) thermometer (*c*) hydrometer.
8. The altimeter is used by (*a*) farmers (*b*) doctors (*c*) aviators.

——Science activities for fun——

1. Make a model stratosphere balloon.
2. Find the latest altitude records of airplane pilots. Make a chart to show how high they can fly.

5. Is air a simple substance?

Many centuries ago, people believed that air was a simple substance. Other simple substances, they thought, were earth, fire, and water. Today we know that these ancient people did not have enough information to draw true conclusions about air.

From the Metro-Goldwyn-Mayer picture, "Edison the Man"

Air under pressure is used to make a hot flame for melting glass. This scene from a motion picture about Edison's life shows the inventor experimenting with making a glass lamp bulb.

What is a simple substance? We know now that a simple substance is one that cannot be divided or changed into any other substances. Air is not a simple substance, for it has been found to be a mixture of many things.

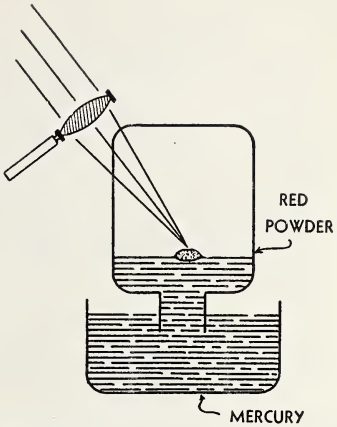
Scientists have found that there are at least 92 simple substances, which are called *elements*. All other materials are made up of some of these elements. Simple substances may mix together without uniting, as you would mix flour and sugar in a cake. Elements may combine by uniting, and form entirely new materials called *compounds*. When you burn a stick, it unites with air and forms several new materials.

You may think of these elements as being similar to letters. When letters combine, or unite, properly, they form words. When they are just mixed together, they do not form a word.

What kind of substance is air? It can be shown that

air is a mixture of several materials, some of which are elements, and others which are compounds. Of the elements in air, one is oxygen [ŏk′sĭ-jĕn]. This element is the one that is used by a fire when we give it a draft. It is the one we need when we breathe.

When a fire burns, oxygen of the air combines with the fuel. Most fuels contain an element called carbon. Carbon is the black stuff you see on a partly burned matchstick. These two elements unite to form a compound called carbon dioxide. The air contains a small amount of this substance. Carbon dioxide in the air is not used by animals but is very important for plants.

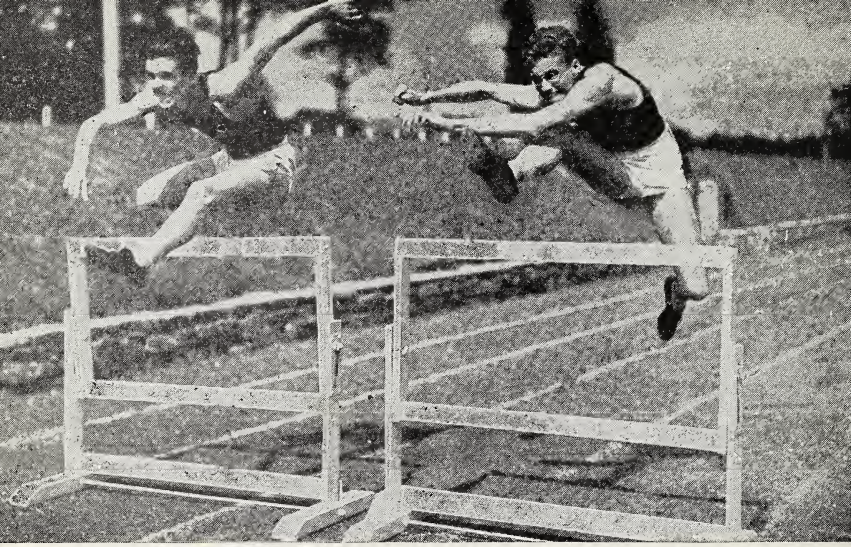


Heat will cause mercury to combine with oxygen. In this experiment there is practically no oxygen left, for the mercury has risen in the jar to replace the oxygen used up in forming the red powder.

Another material given off by a burning stick is water vapor. You can test this by holding in a flame a polished can full of cold water. The water vapor cools and makes little drops on the can. In the same way you can see water vapor from the air collected on pitchers of ice water in summer.

A gas found in the air which is not used directly by animals, and by only a few plants, is nitrogen [nī′trō·jĕn]. Nitrogen is very important because it makes the air suitable for life and regulates the speed of burning. Fires burn so rapidly in pure oxygen that they cannot be controlled. Even an iron stove would burn in pure oxygen. Nitrogen serves a very real need in thinning out the oxygen.

Air also contains other gases, the drops of water which form clouds, and many small solid particles—dust, germs, lint, and small plants.



Courtesy George School

Oxygen of the air is necessary for us to live; and the more active we are, the more oxygen we need.

How did scientists learn what air is made of? An English minister, Joseph Priestley, discovered oxygen when he was using a big burning glass to heat mercury. The glass gathered in the hot rays of the sun, and made the mercury very hot. The mercury became covered with red powder. Priestley reasoned correctly that something had come from the air to unite with the mercury to form the red powder.

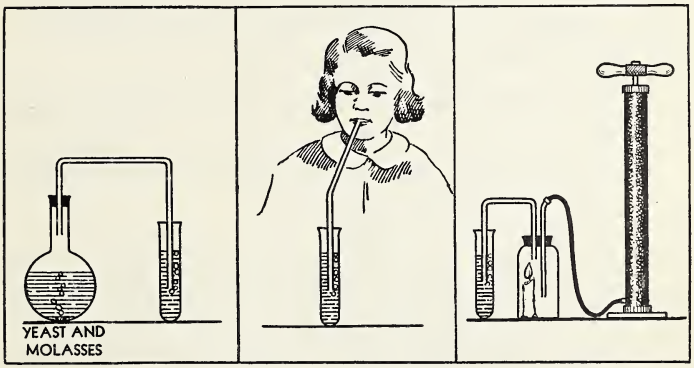
Priestley then put some of the red powder he had made into a dish which he floated in water. Over the dish he put a jar, and pumped the air from the jar. The water rose until the dish floated at the top of the jar. Then again he directed the beam from his magnifying glass on the powder, and it changed back to mercury. He found that a colorless gas was freed which forced the water down in the jar. When the jar was full, he drew off some of the gas and tested it. In air a stick of wood with a glowing spark on the end will go out slowly. When he put such a stick in his sample of gas, the

spark burst into flames. Priestley put a mouse into the gas, and it lived. Later he tried some himself, and found it was good to breathe. He called it "good air." We call it oxygen.

In order to prove that oxygen was part of the air, he put some mercury into a dish under a jar containing air. The mouth of the jar was under water. He heated the mercury with his magnifying glass, and found that the red powder formed again, using up some of the air in the jar. The gas which was left was not fit for breathing or burning. He did not know what it was.

A French scientist, Lavoisier [là·vwà·zyā′], who did the same experiment, found that four-fifths of the air was left after the oxygen was removed. This gas is what we call nitrogen.

After these scientists discovered that oxygen was used up in burning, it was fairly simple to collect some of the gas formed by fire. This gas is easy to test, for when it is mixed with limewater, the limewater turns milky white. This simple test shows that carbon dioxide is present. When you



The three common sources of carbon dioxide in the air are decay, breathing, and burning. Yeast decomposes sugars in a kind of decay. All living things give off some carbon dioxide. Burning fuels release much carbon dioxide. The liquid used to test for carbon dioxide is limewater. What changes would you expect to occur?

blow your breath into limewater, its color turns milky. This shows that there is carbon dioxide in your breath. If you blow air from a bicycle pump into limewater, it turns milky very slowly. This comparison shows that you produce carbon dioxide in your body.

What is air? Air is a mixture of several gases. Air without water vapor in it is about four-fifths nitrogen and one-fifth oxygen. There are only three parts of carbon dioxide in 10,000 parts of air. Even this small amount of carbon dioxide is enough to keep all the green plants alive, and enables them to make food. In air, about one part in a hundred is made up of several other gases, which are less important than the three chief gases.

Air contains water vapor. Water vapor is invisible and is not wet. It is a gas, not a liquid. It is impossible to say just how much water vapor there is in air, for the amount is constantly changing.

You can see where water vapor comes from by looking at a boiling teakettle. Between the spout and the cloud of steam there is a clear space. In this space there is water vapor. Farther away from the spout, the steam disappears and again becomes invisible water vapor.

Demonstration. How Do We Study Gases of the Air?

What to use: Test tube, burner, red mercury oxide, splinter, limewater, glass tube.

What to do: (A) Put as much red mercury oxide into the test tube as will stay on the point of a pen knife. Make a spark on the end of the splinter, and thrust it into the test tube, near the bottom. Heat the tube in the flame until the flame becomes yellow. Test again with the splinter, and if nothing happens, continue heating and testing.

(B) Into half a test tube of fresh limewater blow your breath through the glass tube.

What was observed: How does the splinter burn?

What collects on the sides of the heated test tube? What changes do you see in the limewater?

What was learned: Select the two correct conclusions.

(*a*) Heating the tube drew enough air into it to make the splinter burn.

(*b*) Oxygen, which causes burning, is driven from the red powder by heating.

(*c*) The limewater test shows that the breath contains carbon dioxide.

(*d*) We can heat limewater with our breath to make oxygen.

Things to think about

Write the numbers from 1 to 9 on a piece of paper or in your notebook. The first list contains the subjects of sentences, the second list, the predicates. Match the subjects and predicates. Write after the number of the subject the letter of the predicate which makes a true statement.

Subjects

1. Oxygen
2. Mercury
3. Nitrogen
4. Elements
5. Mice
6. Carbon dioxide
7. A splinter
8. Lavoisier
9. A compound

Predicates

A. is formed when a stick burns in the air.
B. can live in oxygen but not in nitrogen.
C. experimented with gases of the air.
D. when heated in air forms a red powder.
E. burns faster in oxygen than in air.
F. is the most abundant substance in the air.
G. are simple substances which cannot be divided further.
H. is essential for burning and breathing.
I. is made up of two or more elements.

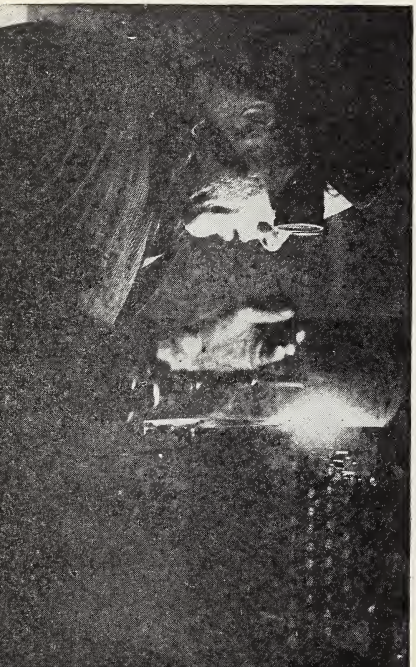
——Science activity for fun——

Force a wad of moistened steel wool into the bottom of a narrow bottle, tight enough that it will stay. Invert that bottle in a cup of water. Observe what has happened after the bottle has been left standing a day. Measure the height the water rose. The gas remaining is nitrogen. Test it with a glowing splinter.

6. How important are the gases of the air to us?

The gases of the air are naturally most important to us because they maintain life. But we have learned so many things about these materials that we use them in many important and surprising ways.

This man is welding the frame of a typewriter. The metal rod in his left hand is melted and flows into the crack to help melt together the broken pieces of metal. The oxygen and fuel flow through the pipe in the man's right hand.



One of the results of studying air was development of the science of chemistry [kĕm′ĭs·trĭ]. Chemistry is the science which makes possible the refining of metals; the manufacture of soaps and artificial leather; the production of cement, glass, and paint; and the manufacture of cosmetics, foods, and artificial fabrics.

How is pure oxygen obtained? Pure oxygen is taken from liquid air. Air may be cooled until it becomes a liquid. Oxygen becomes liquid at a temperature of nearly 300 degrees below zero. Nitrogen does not become a liquid until the temperature is almost 350 degrees below

zero. When liquid air is warmed up, the nitrogen escapes first and leaves the oxygen behind. Oxygen is put into steel tanks to be shipped to the buyer.

How is liquid oxygen used? Oxygen sold in tanks is used more in welding, or melting together, metals than in any other way. When used with some kind of fuel gas, it makes a very hot flame which will weld pieces of metal. A special kind of illuminating or cooking gas is put into tanks to burn with the oxygen. These gases are run through separate pipes to a burner, where they combine to produce a very hot flame. A welding flame melts metal just as an ordinary flame melts ice. Welding is used to join together pieces of pipe, to mend broken farm machinery and automobiles, and to put together the pieces of metal used in making automobile bodies and many other large machines.

Oxygen frequently is used to revive people who have nearly drowned or who have been overcome by smoke or heat. In this use, a piece of apparatus is put over the mouth and nose of the person, and measured quantities of oxygen are released for him to breathe. Since one breath of oxygen is equal to five breaths of air, people who are ill with certain diseases also are treated with oxygen to lessen the effort required in breathing.

Aviators require oxygen for flying at high altitudes. A special device for breathing oxygen has been developed which permits the pilot to talk through his radio while breathing oxygen. A picture of four men who are wearing these oxygen masks is shown on page 121.

Is oxygen used in nature? Have you ever thought how cluttered up the world would be if there were no decay? When things decay, they are caused to combine with oxygen by the action of simple plants. Dead plants and animals are changed by decay to carbon dioxide, water, and some solid materials which are left behind. Drinking water is sometimes sprayed into the air to kill some kinds of small plants which grow in it. However, oxygen in water does not kill germs, or make the water safe to drink.

Courtesy the Bastian-Blessing Co.

Carbon dioxide is the gas which "fizzes up" in soda water. Can you find a way of testing the gas from a bottle of pop?

Oxygen is the most essential gas required by animals. The supply of oxygen is renewed by plants, which release it from carbon dioxide in making food.

How useful is carbon dioxide? In our first experiment, a candle was put out by pouring vinegar on baking soda in a glass. The gas given off by the soda was carbon dioxide. This experiment shows that carbon dioxide will put out a fire by smothering it. Carbon dioxide is produced in the kind of fire extinguishers that must be turned upside down to work. The gas formed causes the water to squirt out, and helps the water put out the fire.

Have you ever watched a fountain attendant make an ice-cream soda? He puts some ice cream and sirup into a glass, and then adds water mixed with carbon dioxide. The warmth of the air and the lower pressure causes bubbles to rise, which are caught in the ice cream to make an appetizing-looking foam. The carbon dioxide is stored under the fountain in a metal tank, and is mixed with the water by a valve which the attendant operates.

All forms of bottled soft drinks contain carbon dioxide. Liquids which are formed by fermentation [fûr′mĕn·tā′-shŭn, a change caused by yeast], and not boiled afterward, contain carbon dioxide. Such liquids as beer, ale, and some ciders and wines contain carbon dioxide. Of course these drinks contain alcohol, which is also formed by fermentation.

The bubbles in bread, produced by fermentation of sugar by yeast, contain carbon dioxide. Both the gas and the alcohol in bread are driven off by baking.

Baking powders contain soda and some dry chemical, which when wet acts on the soda to produce carbon dioxide. Many patent medicines contain some chemical of this type to make the medicine "fizz." Some people think that the medicine is better because it looks active when the bubbles of carbon dioxide escape.

"Dry ice" is really solid carbon dioxide. It may be made from the gases escaping from chimneys. Also used for making dry ice is the carbon dioxide given off in making lime from limestone. An advantage of dry ice over ordinary water ice is that it is much colder. When solid carbon dioxide is warmed, it does not form a liquid, but changes directly to a gas. Therefore it is less messy than water ice.

Is water vapor important to us? A sufficient supply of water vapor in the air makes us feel comfortable. Water vapor is carried from the ocean to the land to fall as rain. Water vapor in the air makes it light in weight, for it is the lightest of the common gases in the air. The amount of water vapor thus has some effect on the air pressure.

At first it is difficult for us to think of water vapor as being dry gas. You cannot wet anything with water vapor any more than you can wet it with very cold ice. Water is wet only when it is a liquid.

A common method of drying materials is to put them in the sun. The water passes as vapor into the air. These apricots will soon be dry enough to put into packages.

Courtesy Chattanoogans, Inc.

Around the edge of his field the farmer has planted a crop which provides nitrogen to the soil. It also provides a place for game birds to hide and to find food.

What value are the other gases in the air? As you already know, nitrogen is necessary for life. Certain small plants called bacteria [băk·tēr′ĭ·*a*] can take nitrogen from the air and put it into the soil. Nitrogen is taken from the air and made into fertilizer for crops in some factories. Nitrogen is used in large lamp bulbs to keep the hot wires from burning as they would do if exposed to air. Sometimes argon [är′gŏn], another gas from the air, is also used in lamp bulbs.

Demonstration. What Can We Discover about Air?

What to use: Beaker or jar, cover, candle, limewater, flask, soda, hydrochloric acid, one-hole stopper for flask, delivery tube, test tube.

What to do: (A) Put the lighted candle in the jar, and cover it. When the flame goes out, carefully remove the candle, pour in some limewater, and replace the cover, being careful not to pour out the gases in the jar.

(B) Pour some acid in water in the flask. Put the limewater in the test tube. Arrange the delivery tube to run gas into the test tube from the flask. Pour some soda into the flask, and instantly put the delivery tube and stopper in place.

(C) In one beaker place a lighted candle. In an-

other beaker run some gas from the flask, adding more chemicals if needed. Keep the second beaker partly covered as gas runs into it. Then carefully pour the gas from the beaker into the one containing the candle.

What was observed: How long does the candle burn? What does it use up? To what color did the limewater turn? What gas is given off by soda? Will this gas put out a flame? How do you know?

What was learned: Select the *two* correct conclusions.

(*a*) Carbon dioxide will not burn or support burning.

(*b*) Carbon dioxide is lighter than air.

(*c*) A candle burns in a jar until it uses up the carbon dioxide.

(*d*) A candle burns until the supply of oxygen is gone.

——Things to think about——

Write the numbers from 1 to 10 on a piece of paper or in your notebook. Complete the following sentences to make true statements. Opposite each number write the word needed to complete the sentence.

A gas used in welding is —1— because it makes fuels burn better than does air. —2— is used by aviators. Baking powder gives off —3— which makes bubbles in bread. —4— is used in light bulbs. The science of —5— is used in manufacturing soap. Fire may be put out by smothering it in —6—. —7— is the only gas in the air which supports burning. —8— is used in all green plants in making food. Soda pop contains a gas called —9—. Dry ice is —10— than water ice.

——Science activities for fun——

1. Visit your local ice plant or ice-cream factory. Ask to see some solid carbon dioxide. Find out how it is made. How

Courtesy Chicago Park District

These beautiful chrysanthemums are made in part from the carbon dioxide of the air. When air is enclosed in the greenhouse, it is possible to keep it warm.

cold is it? Why is it better to use than ice? Test some with limewater. What happens to the limewater?

2. Visit a cave which has been formed in limestone. Look for hanging pieces of limestone. Find out how these were formed.

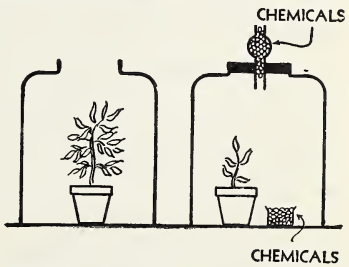
7. How do living things use air?

We have seen that mice cannot live without air containing oxygen. Since mice are representative of all animal life, it is safe to believe that all animals must have air. If a plant had been used in the experiments with oxygen and nitrogen, we would have seen that plants need air just as much as do the animals. Plants and animals do not depend on the oxygen of the air alone but also make use of carbon dioxide, nitrogen, and water vapor.

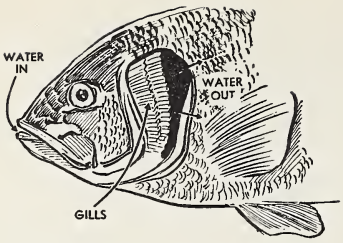
How do plants use air? To obtain energy for growth, food must be burned—just as fuel is burned to provide energy to run engines. Plants, as well as animals, require energy. To use the food, oxygen must be taken in and combined with it. Of course this process is much slower than burning. Plants store food which they must use in growing. When peas or other seeds sprout, they use up the stored food to feed the tiny plant that grows from the seed. If you put some seeds into a closed bottle with enough water to keep them moist, they may burst open, but the young plant will not grow. A similar bottle which is not stoppered will produce plants of considerable size. This experiment shows that plants need air.

That plants use carbon dioxide may be shown by the following experiment. Two plants are started in the same kind of soil and kept in the same light. A jar having an opening for air is placed over each. One jar has the opening protected by a tube containing a chemical which removes the carbon dioxide from the air before it reaches the plant. The other jar permits ordinary air to enter. It is found that the plant which does not receive carbon dioxide does not grow, but the other plant does. Some plants obtain their food by feeding on other living things. These plants will grow without carbon dioxide, since they obtain it through the other living things. Plants which depend upon carbon dioxide for life are nearly all green plants.

Bacteria which use nitrogen leave it in the soil when they die. Other plants need nitrogen to build certain parts such as seeds and leaves. They cannot get this nitrogen from the air but must take it from the soil.



The chemicals absorb the carbon dioxide from the air which enters the jar. The other jar is open. What gas seems to be necessary for the growth of plants if the two plants were once the same size?



The covers of the gills have been removed. Water flowing through the fish's mouth flows out past the gills which absorb oxygen from the water.

How do animals use the gases of the air? The gas in the air most needed by human beings is oxygen. Other animals have the same needs. No other gas can be used in its place. It is easy to understand how animals living in the ground or in the air can obtain enough oxygen, but it is more difficult to understand how animals living in water can breathe.

How do water animals obtain oxygen? If cold water is heated gently in a glass beaker, bubbles can be seen collecting on the sides of the beaker. These bubbles will gradually rise to the surface. If enough water is heated and the bubbles are collected, the gas can then be tested for oxygen. The gas thus formed is not all oxygen, but it can be shown that the air found in water contains more oxygen than does ordinary air.

Animals which live in water obtain their oxygen by using organs different from those used by land or air animals. Fish have slits just behind the head, through which water flows. Inside these slits are layers of pink, comblike *gills* through which the water is strained. The gills contain many blood vessels close to the surface, so that oxygen may be aborbed from the water. Fish placed in cool water which has been recently boiled will soon die. If a fish is put in limewater for a few minutes, the limewater turns milky. This experiment shows that oxygen taken in by the fish is given out combined with carbon as carbon dioxide. Tests similar to this show that all animals give off carbon dioxide.

How does water vapor affect animals? As food is used to supply energy, water, as well as carbon dioxide, is formed as a waste product. You can show that there is water vapor in your breath by blowing on a cold, polished surface. Fine

drops of water form. In the winter moisture from our bodies forms on the glass of automobiles in which we are riding. Much of this waste water is given off through the skin. We are very conscious of it during the summer when it may stand on our bodies in drops.

All animals must get rid of this extra water. As the water escapes into the air, heat is absorbed from the body. This absorption keeps the body cool. Dogs lose most water through their tongues. You have seen water dripping from a dog's tongue on a hot summer day. This is the dog's way of keeping cool.

If the air is very dry, water is lost rapidly, and the body may cool too much. When the air is filled with water vapor, we cannot lose heat fast enough, and we feel uncomfortable. It can be shown that all things are affected in this way by the amount of water vapor in the air.

Does air contain other things of importance to us? Many living things besides insects and other things which we can see are carried by the air. Some of the smallest of these living things are the plants which cause decay and spoiling of food. These plants are so small that only good microscopes will show them at all.

You may have wondered why foods spoil when they are exposed to the air for some time. Ancient peoples answered this problem by saying that food spoils itself. Nearly a hundred years ago, a great scientist, Louis Pasteur [päs·tûr′], cooked some beef broth and, while it was still hot, sealed it in a glass bottle by melting the bottle neck until it closed. The broth remained clear and unspoiled. Pasteur concluded that the things which cause spoiling come from the air.

Since the time of Pasteur, many experiments have proved that he was right. The tiny plants which cause sweet mixtures to change to alcohol and give off carbon dioxide are the yeasts which are carried by the air. Yeast, which has been "tamed" and mixed with starch or corn meal, is sold to make bread rise. This kind of yeast is only one of many kinds.

Courtesy Ball Brothers Company

In canning corn or any food, we kill by thorough cooking the small plants which cause decay, and then we seal the can without air in it. If the food is not well cooked or if the cover is loose, the food will spoil.

There are other tiny plants which cause bread to mold. Still others cause diseases of plants. Spores [spōrz, tiny seed-like objects] of these plants have been found in the air everywhere. In tests made almost two miles high, many different types were found. Some of these plants were the ones causing plant diseases. Is it any wonder that it is difficult to protect garden plants or flowers from the brown spots and wilting caused by such little plants?

DEMONSTRATION. DO PLANTS NEED AIR?

What to use: Two bottles, stopper, peas or beans, blotting paper.

What to do: Put into one bottle several folds of blotting paper. On the blotting paper place a number of seeds (beans or peas) and put enough water in the bottle to keep the seeds wet without covering them. Close the bottle tightly with the stopper. In the other

bottle place some more blotting paper and the same number of seeds. Add enough water to wet the seeds as before, but do not stopper.

Look at the seeds every day for several days.

What was observed: How long does it take the seeds to sprout? Do seeds in both containers sprout at the same time? Do you notice any evidence of spoiling in either place? Which finally turns out best?

What was learned: Select the correct conclusion.

(*a*) Air is necessary for the sprouting of seeds and the growth of small plants.

(*b*) Seeds spoil when exposed to the air on a moist blotter.

(*c*) Where seeds are placed makes no difference in their rate of growth.

——Things to think about——

Write the numbers from 1 to 9 on a piece of paper or in your notebook. Opposite each number write the letter before the word or group of words which best completes the sentence.

1. If a fish is placed in freshly boiled and cooled water, the fish cannot live because (*a*) the heat is still in the water (*b*) boiling drives air from water (*c*) it cannot swim in boiled water.

2. The gas in the air used in greatest amounts by green plants is (*a*) water vapor (*b*) carbon dioxide (*c*) nitrogen.

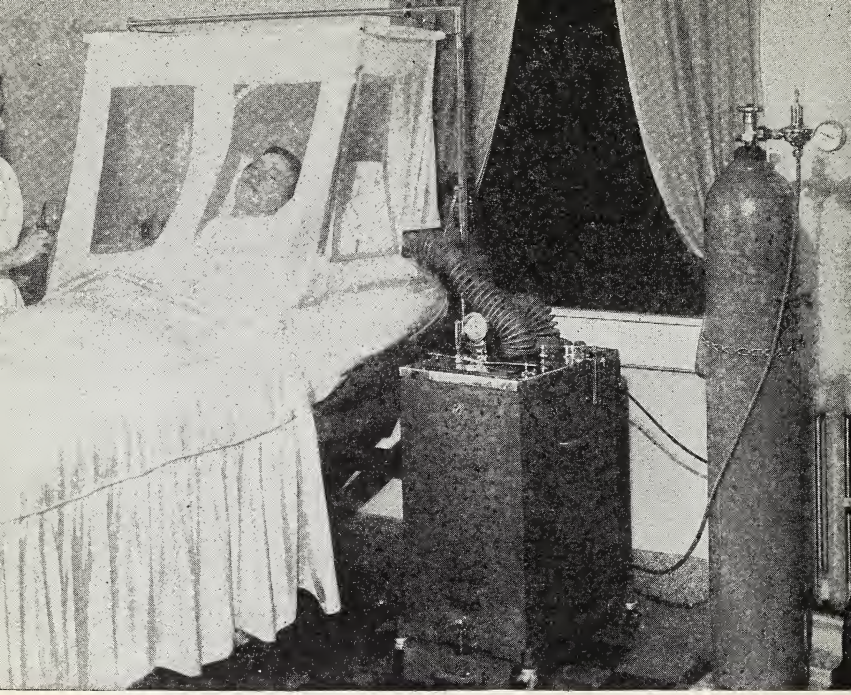
3. Nitrogen can be used only by (*a*) bacteria (*b*) fish (*c*) green plants.

4. Fish take in oxygen from the water through their (*a*) skins (*b*) gills (*c*) lungs.

5. The gas in the air upon which animals depend most is (*a*) water vapor (*b*) carbon dioxide (*c*) oxygen.

6. Nitrogen which plants use for food is in the (*a*) water (*b*) air (*c*) soil.

7. The bŏdy loses water through the skin very rapidly if the air is (*a*) very wet (*b*) very dry (*c*) light.



Courtesy Linde Air Products Co.

This device is called an oxygen tent. The oxygen is stored in the steel tank and is run through the machine which regulates the moisture, pressure, and temperature.

8. Louis Pasteur found that the things which cause food to spoil come from (*a*) animals (*b*) the air (*c*) the food.

9. Tests show that all animals give off (*a*) carbon dioxide (*b*) oxygen (*c*) nitrogen.

——Science activity for fun——

Do some of the experiments suggested in this problem. Demonstrate them to the class.

8. How does air affect our health?

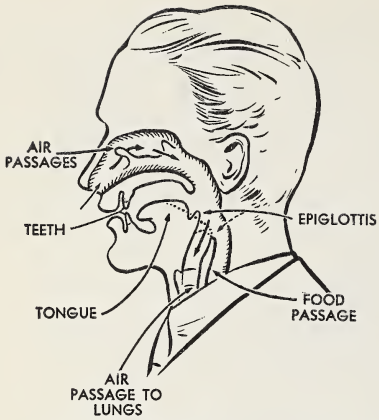
Nearly all the things we have discovered about air so far have been helpful to us. There are some things about air and

its use which may help us in keeping well. Air carries with it large amounts of dust and other impurities. Although each breath does not contain a great deal of air, it is surprising how much air a grown man will breathe in a day. He takes an average of about 20 breaths a minute. Every 24 hours more than 60 large barrels of air move in and out of his lungs. This would fill about one-half of an average bedroom.

How are we protected from impure air? Our best protection from some kinds of impure air is the nose. There are three things which the nose does for us. First, the air is warmed in the nose to a temperature nearly equal to that of the body. When one is healthy, the body temperature is 98.6 degrees, while the average temperature of the air is much lower. Second, the air is moistened by the nose. Dry air is injurious to the lungs, and causes us to catch diseases easier. Third, many impurities are caught and stopped by the nose. Dust is caught in the moist lining of the nose and also on the tiny hairs in it, which also stop larger objects. Bacteria are stopped to some extent as the air passes over the inside of the nose. The mucus [mū′kŭs, protective liquid] which is produced inside the nose has some power to kill bacteria.

Spores of some disease bacteria are carried by the air. Either the spores of bacteria or the bacteria themselves which cause tonsillitis, sinus [sī′nŭs, a cavity in the bones of the skull] infection, whooping cough, scarlet fever, tuberculosis, and many other diseases are believed to be carried through the air at certain times. For this reason, it is well not to go into a sickroom where these bacteria are present. Spitting puts germs where they can be stirred up by wind, by sweeping, and by walking. Spitting is not only unsanitary, but it is also vulgar.

Why is nose breathing better than mouth breathing? The nose is so built that the air stays in it longer than air does in the mouth. The nose passages are crooked, and there are folds in the walls of the passages. This makes a long lining surface to catch dust. There are more blood vessels to warm



Air is moistened and warmed as it goes through the winding passages of the nose. The epiglottis is a little gate which closes the food tube when we swallow. The dotted line shows it closed.

the air in the nose than there are in the mouth. The mouth is a large opening through which air passes quickly. It has no parts which clean and warm the air. In fact, the mouth may be the lodging place for bacteria.

Removing enlarged adenoids [ăd'ė·noidz, growths of tissue at the back of the nose and throat] sometimes makes breathing through the nose easier. The nose may be deformed in some way, because of injury, making it necessary to open the passages by operation. If a condition which causes a person to breathe through his mouth is left unattended for a long time, the shape of his face is changed, harming his appearance.

One of the most important things to do for good health is to avoid catching colds. Good defenses against colds are breathing pure, moist, fairly warm air; forming regular habits of eating and getting rid of body wastes; and obtaining plenty of rest. Sleeping cold, exposure, loss of sleep, being around others who have colds, getting too tired, and eating improper food make one more likely to have colds.

Can the body protect itself against all impure air? There are many things in the air against which we have no protection. Air may carry small amounts of many poisonous substances. The automobile engine produces a deadly gas against which there is no protection in the body. A leaking exhaust pipe may permit enough of this gas to get into closed automobiles to cause those people in the autos to have headaches, and in closed garages this gas frequently causes death. Crowded city streets may contain enough of it to be injurious.

Many people are sensitive to pollen [pŏl′ĕn, usually yellow dust] given off by flowers, or the dust from feathers, animals, and hay. They suffer from a disease of the nose and throat called hay fever, or from a skin eruption. To these people pure air is very important, and they often travel long distances to find air which does not contain the dust which makes them ill. One person in every ten has hay fever part of the time, most often in the late summer.

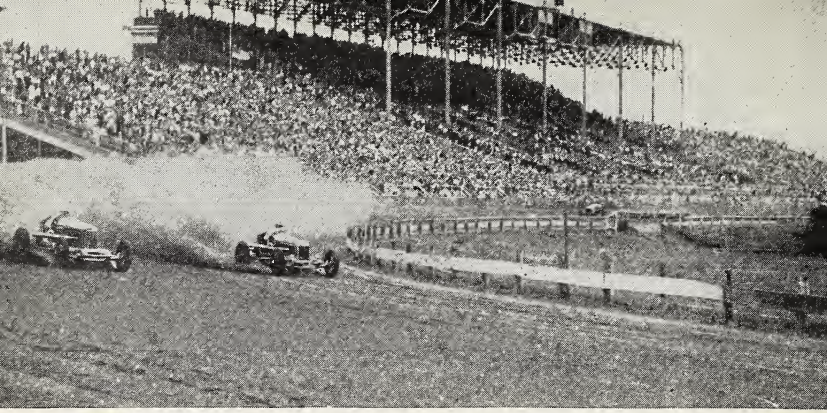
Why must we breathe at all? Oxygen is needed to support life, but just how does it aid us in keeping alive?

We need energy to do those things which make the difference between being alive and not being alive. You know already that oxygen is needed by fires. The fire burns and gives off heat and light, which are forms of energy. Our bodies give off heat, and can move from place to place. Parts of the body move all the time.

The food we eat combines with oxygen in somewhat the same way that fuel does. There is no particular place in the body where this combination takes place. In fact, every bit of the body that is living does its share. The muscles, the

In this modern hospital the beds are separated by glass partitions to prevent bacteria from being carried by the air from one patient to another.

Courtesy U. S. Public Health Service



Eugene Rosing photo

Practically everything that we do depends upon air. The engines, the drivers, and the spectators are using air. The tires contain air. The air carries the dust thrown up by the wheels.

nerves, the skin, the lining of the cavities of the body, parts of the bones and teeth, and places in the body which make chemicals—all are using energy, and getting it by combining food with oxygen. The oxygen from the lungs and food from the intestines are carried by the blood to the parts of the body where they are used.

The rate at which we use oxygen depends upon what we do. If we climb a mountain we need much more energy than if we sit idly in the shade of a tree. As the mountain climber starts walking, he soon begins to "get out of wind," which is a good way of describing his trouble. Soon the muscles of the chest, which do the breathing, get more energy, and the mountain climber breathes faster. As more oxygen is supplied to the blood, the muscles work better, and the mountain climber gets his "second wind."

The amount of air used in breathing can be measured. The air from the lungs is blown into a bag and tested. Oxygen that is used in the body forms carbon dioxide. The carbon dioxide given off is measured. More carbon dioxide is given off by people when they exercise than when they are quiet. This type of experiment proves that we use more air

when we exercise, and shows that our everyday observations about exercising and breathing are correct.

DEMONSTRATION. DOES A MOIST SURFACE HOLD DUST BETTER THAN A DRY SURFACE?

What to use: Lamp chimney, two rubber bands, cheesecloth, dust or chalk or flour, spoon.

What to do: Place the lamp chimney on its side, and in about the middle of the chimney put a spoonful of flour. Put over each end of lamp chimney a piece of cloth, and fasten it with a rubber band. Thoroughly moisten one cloth, without having it too wet, and leave the other dry. Shake the lamp chimney to stir up a dust inside it. Observe from which end the dust escapes.

What was observed: Does the dust escape equally from both ends, or does the water cause it to escape more slowly from the moist end? Which cloth holds more dust at the end of the experiment?

What was learned: Select the correct conclusion.

(*a*) Moist surfaces help dust to escape by making the surface smoother.

(*b*) Dust escapes through small openings in the same manner whether the surface is wet or dry.

(*c*) A moist surface holds dust and keeps it from escaping.

——Things to think about——

Write the numbers from 1 to 10 on a piece of paper or in your notebook. Complete the following sentences to make true statements. Opposite each number write the word needed to complete the sentence.

Bacteria sometimes grow from tiny seedlike objects called —1—. The nose —2— the air, makes it more —3—, and re-

moves some of the —4— from it. When oxygen combines with food it gives the body —5— to move. —6— is caused by pollen of plants. When we —7—, the room should contain air that is fresh and not very cold. —8—, which are growths of tissue at the back of the nose and throat, sometimes hinder breathing. —9— are cavities in the bones of the skull. More —10— is given off when people exercise than when they are quiet.

——Science activity for fun——

Find out how much air you breathe in an average breath. Obtain a gallon water bottle, a two-hole rubber stopper, some glass tubing, some rubber tubing, a large pail, and a measuring cup. Insert a three-inch piece of glass tubing so that it is just through the stopper. Attach to the outer end a short piece of rubber tubing through which to blow. Insert a piece of glass tubing, long enough to reach the bottom of the water bottle, through the other hole of the stopper. Attach a piece of rubber tubing to the outer end of this to carry the water to the overflow pail. Fill the jug with water. Take an average breath and blow into the jug. Measure the water which overflows with a measuring cup. (*Warning:* The end of the outlet tube must be kept higher than the level of water in the jug. Why?)

A Review of the Unit

We know that air is a real substance. It has weight, exerts pressure, and can be measured. It will expand to fill any container. Therefore we say it is elastic. Air is a mixture of gases, the most important of which is oxygen. Besides its immediate use for supporting life, it affects our living in many other ways. Nitrogen and carbon dioxide are nearly as important since they must be used to build tissues for growth. Water vapor, a waste product of living, helps to

regulate temperature and air pressure. Good health depends greatly on correct use of air.

An exercise in thinking

Below are two groups of sentences. The first group contains principles, which are large general ideas. Each sentence in the second group contains an idea related in some way to one of the principles in the first group. Write the numbers from 1 to 32 on a piece of paper or in your notebook. Find the principle which best explains the idea in the second list. Then after the number on your paper write the letters before the related principle.

Example: We can see air when it bubbles through water.

The correct letter for the example sentence is **A** *because we see air when it occupies space in water.*

List of principles

A. Air is a real substance because it has weight and occupies space.

B. Air exerts pressure because it has weight.

C. Air exerts pressure on containers because it is elastic.

D. When air is heated it expands, and when cooled it contracts.

E. Hot air is lighter in weight than cold air.

F. Air pressure becomes less as the elevation increases.

G. Oxygen in the air is necessary for burning and for life.

H. Carbon dioxide and water vapor are given off when oxygen is used for breathing, burning, or decay.

I. Impurities carried by the air may injure our health.

List of related ideas

1. More than 60 barrels of air pass in and out of the lungs daily.

2. Limewater turns milky when we blow our breath through it.

3. A football pumped up weighs more than an empty football.

4. Basketballs bounce.

5. It is difficult to breathe on high mountains.

6. The cork may pop out of a cold bottle brought into a warm room.

7. People suffer most from hay fever in the summer.

8. Cold air in a room settles to the floor.

9. Mice cannot live in a jar of nitrogen.

10. An inflated football keeps its shape well.

11. Water vapor in air is an important aid to good health.

12. An open topped container is never empty.

13. A candle burns only for a moment in a closed jar.

14. Fish living in water must breathe air.

15. Pure air is necessary for good health.

16. Air rises above a hot radiator.

17. Air pressure is measured by a barometer.

18. Some people have nosebleed on high mountains.

19. Yeast and sugar in water together give off carbon dioxide.

20. Tires become harder on hot days.

21. An omelet rises when cooked.

22. Water does not run from a chicken fountain until air enters.

23. One cannot drink through a tube from a closed bottle.

24. The wind is really air in motion.

25. Stratosphere balloons become rounder as they rise.

26. A glowing splinter bursts into flame in oxygen.

27. Sprouting peas will not grow in a closed bottle.

28. We should form the habit of breathing through the nose.

29. There are no empty spaces in soil.

30. Balloons stretch when blown up with air.

31. There is more carbon dioxide over cities than over lakes.

32. Air containing an excess of water vapor is lighter than dry air.

An exercise to test yourself

Write the numbers from 1 to 12 on a piece of paper or in your notebook. Opposite each number write the letter before the word or group of words which best completes the sentence. Some sentences may have more than one correct answer.

1. The space between particles of wood, bread, and soil is filled with (*a*) a liquid (*b*) water (*c*) nothing (*d*) air.

2. Winds are caused by (*a*) moving branches of trees (*b*) differences in clouds (*c*) differences in air pressure (*d*) lightning.

3. A gas present in ordinary air in small amounts and in air which comes from the lungs in larger amounts is (*a*) nitrogen (*b*) oxygen (*c*) neon (*d*) carbon dioxide.

4. The experiment in which the football is weighed shows that air (*a*) has weight (*b*) is elastic (*c*) contains water vapor (*d*) under pressure is lighter than ordinary air.

5. The air above the earth's surface is called (*a*) a vacuum (*b*) a hemisphere (*c*) the atmosphere (*d*) the stratosphere.

6. Oxygen of the air is necessary for (*a*) burning of wood (*b*) blowing of wind (*c*) formation of snow (*d*) inflating basketballs.

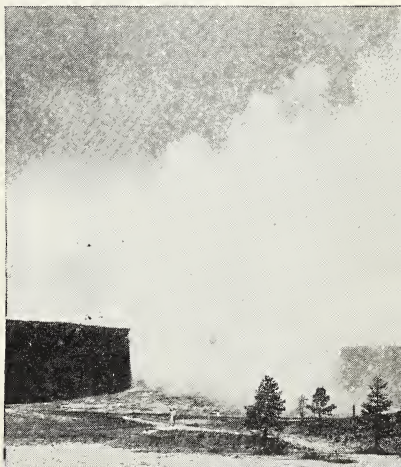
7. When iron rusts, it unites with (*a*) nitrogen (*b*) oxygen (*c*) water vapor (*d*) carbon dioxide.

8. Air is composed chiefly of (*a*) oxygen and nitrogen (*b*) carbon dioxide and oxygen (*c*) water vapor and nitrogen (*d*) nitrogen and carbon dioxide.

9. The most abundant gas

Air can support drops of water. Here the wind blows the water sidewise from Old Faithful geyser in Yellowstone National Park.

Courtesy U. S. Department of the Interior



in the air is (*a*) nitrogen (*b*) oxygen (*c*) water vapor (*d*) carbon dioxide.

10. Limewater is used to test for (*a*) nitrogen (*b*) oxygen (*c*) water vapor (*d*) carbon dioxide.

11. The part of the air which will support burning is (*a*) nitrogen (*b*) oxygen (*c*) water vapor (*d*) carbon dioxide.

12. Living things carried by air are (*a*) tiny plants (*b*) birds (*c*) insects (*d*) animals.

Some things to explain

1. Does an athlete run with less panting for breath at sea level or on a high plain?
2. Why can't we breathe under water as a fish can?
3. Why are airplanes fitted with airtight cabins?
4. What businesses in your local community use oxygen? Carbon dioxide? Dry ice? Chemicals?
5. Who started the science of chemistry? (Look up Lavoisier, Priestley, and Pasteur before deciding.)
6. Is any gas in the air moist?

Some good books to read

Compton's Pictured Encyclopedia
Fisher, Irving and Fisk, E. L., *How to Live*
Humphreys, Pauline A. and Hosey, Gertrude, *Romance of the Air*
Jameson, P. R., *The Barometer as the Foot Rule of the Air*
Meister, M., *Water and Air*
School Ventilation, New York Commission on Ventilation
Talman, C. F., *Realm of the Air*
Winslow, C. E., *Fresh Air and Ventilation*
World Book Encyclopedia

Courtesy C.P.R. W. J. Gibbon photo.

Lake Louise, Alberta Rockies.

UNIT SIX-B

HOW DOES WATER SERVE US?

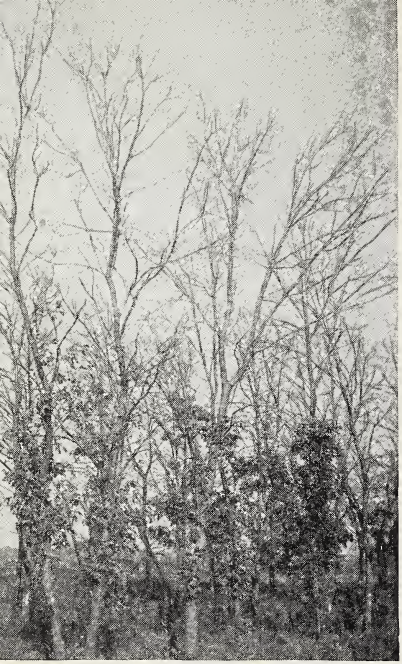
We see water in all its forms nearly every day, but because it is so common we usually pay very little attention to it. Yet it is constantly changing, appearing now as running water in streams and fountains, again as steam to heat our homes and operate powerful engines, sometimes as clouds relieving the blue expanse of sky, or at other times falling as rain or snow. Later we find it solid, hard, and dry in the form of ice which brings welcome relief from heat, preserves our food, or makes it difficult for us to walk on sidewalks or pavements.

Water acts slowly upon many things to dissolve them and wash them away. Thus great caves are formed, and we are able to keep clean. But of even greater importance to us is the fact that water is the chief means for transporting food to all parts of the body and for removing wastes. In nearly all plant and animal tissues, large amounts of water are confined either as a part of the compounds of which they are composed or as free liquid enclosed by the blood vessels. Should the temperature of the earth change so that it remained below the freezing point of water, all life would disappear.

Many forms of plants and animals live in or on the water, and we are dependent upon them for a part of our food. Water gives us pleasure by carrying our boats, or by supporting our bodies while we swim.

Safely under control, water serves as a source of power and an avenue for travel and transportation. Driven by strong winds or in floods, water escapes natural or man-made boundaries and brings destruction and death to many things in its path. Evidence of the force which it can exert is found in the deep canyons carved through the mountains.

Water is an amazing substance. How can it do so many different things? How does it change its form? How can our streams and rivers keep continually flowing to the sea? Why is water so important to living things? How can water support great ocean vessels made of materials that are many times heavier than water? When you read this unit, you should be able to answer these and many other questions.



Courtesy U. S. Soil Conservation Service

These green ash trees are partly killed by dry weather. The tops of these trees will never recover from the effects of insufficient water.

1. How are living things dependent upon water?

Most scientists think that the first life upon the earth developed about a million and a half years ago in water along the edge of the ocean. These living things were so simple that they looked more like chemicals or jelly than like the living things on earth today. At that time, the earth was not prepared for plants and animals because there was no soil. The existing land had been lifted above the surface of the ocean and was chiefly solid rock. Slowly this surface was enlarged and worn down by the action of the water until great swampy areas were formed which contained materials upon which these early living things could feed. Gradually the simplest plants developed.

During the following millions of years the land was further enlarged, and new types of living things appeared. But all these living things were dependent upon water or very wet areas for their food and protection. Living things today are not greatly different from these early primitive forms, since they all need water. In fact, they cannot live more than a few hours without it.

How do plants use water? When there is not a normal amount of rain, trees may die, crops do not grow, and swamps become dry and lifeless. When there is normal rainfall, most parts of the United States produce plants in plenty.

Right picture courtesy Phoenix Chamber of Commerce

Compare the appearance of the Joshua tree (*right*) and the willow tree (*left*). The Joshua tree is a desert plant related to the Spanish bayonet and to the lily family. It is found in Arizona. Willows require much water and usually grow near rivers, ponds, or lakes.

A few kinds of plants are able to live without water for months, but they store a supply of water in their roots, stems, or leaves when a supply is available. Their leaves are small and do not give off much water. The leaves of the cactus develop into spines which protect the plant from being eaten by desert animals. The cactus plant can remain alive a long time without water. One cactus which had been stored for years started to grow when brought into moist air.

Common leaves have tiny pores on both upper and lower surfaces through which they lose water vapor to the air. Imagine how much surface the willow tree in the picture has through which it loses moisture. Compare it with the Joshua tree next to it. This plant is not a tree, but really is a kind of a lily. Notice how little surface its leaves have.

Many plants must have water in which to live. Green scums, water cresses, many grasses, and seaweeds grow right in the water. Many other plants grow with their roots in water. Plants which grow entirely in water have weak stems, because the water supports their weight. Water plants are not blown by wind or dried by hot weather.

How do animals use water? Every living animal is made up of more water than of any other single material. The flesh itself contains much water. Blood is mostly water. Animals really live in water, for the living parts are always moist. The skin may be considered the outer part of a container of liquid in which the living parts move and grow.

Many animals live directly in water. Many kinds of insects can be caught in a pond by sweeping a large strainer through the water. Fishes, lobsters, crabs, shellfish, and other larger animals make their home in the water.

Starfish are not fish, but water animals which live near the shore in the ocean. Neither are jellyfish real fish; they are animals which are composed of clear masses of watery material. They may be seen floating along in the water.

Are water animals of value to us? Many water animals are of value to us as food. Plants take from the soil many elements which we need in order to be healthy. After many years of farming, the soil no longer contains enough of these materials to keep us well. Since the water in the ocean contains plenty of these important substances, we can get them by using for food animals which live in the sea. At the same time, we get other nourishing food as well. The animals prin-

There is a large group of water animals which produce shells for protection. These animals are related to snails and oysters. These shellfish depend upon water for air and food, as well as water.

cipally used for food are crabs, lobsters, shrimps, oysters, and fishes.

What other living things need water? Some simple living things can do without water for almost indefinite periods of time. During this period, life is suspended. When they are able to absorb water, they will grow again. These forms are generally microscopic in size. They often protect themselves by shrinking and forming heavier outer walls than they usually have. In this form, these simple living things are carried by the air, and are difficult to kill.

Some kinds of mosses live on dry rocks, and in midsummer look completely dead. Yet if there is a shower, they turn green in a few hours and grow as long as the supply of water lasts. During dry weather they become inactive again.

Is water necessary for life? Every living thing that apparently lives without water really has a way of storing water within itself so that it cannot evaporate. If such plants or animals were placed in a drying oven and very gradually and completely dried out without scorching, they would die from lack of water, just as a green plant does when it is dried.

Some plants are protected from freezing in winter by giving off much of the water which they contain. In spring the plant does not grow until water rises from the ground to give it a new water supply. Water is necessary for life.

Demonstration. Do Living Things Contain Water?

What to use: Large green plant or weed, balances.

What to do: Weigh the plant freshly cut from its roots, and make a record of its weight. Dry it by hanging it over a radiator for several days. Weigh it again. Make a record of the weight.

What was observed: How much weight did the plant lose? What per cent was this of the first weight of the plant?

What was learned: Select the correct conclusion.

(*a*) Heat takes much of the weight from a plant.

(*b*) Plants weigh about the same whether green or dried.

(*c*) The loss of weight of a plant when it is dried is equal to the weight of the water lost by the plant.

——Things to think about——

Write the numbers from 1 to 7 on a piece of paper or in your notebook. Opposite each number write the letter before the word or group of words which best completes the sentence.

1. Desert plants have (*a*) broad, thin leaves (*b*) small or thick leaves (*c*) no roots.
2. Life probably first started in (*a*) the soil (*b*) jelly (*c*) the ocean.
3. The green scum in water is (*a*) a plant (*b*) an animal (*c*) dirt.
4. The inside of the body is largely (*a*) water (*b*) bones (*c*) dry material.
5. The most frequently used sea food is (*a*) fish (*b*) lobsters (*c*) oysters.
6. Simple plants are blown through the air (*a*) dried (*b*) in water drops (*c*) on bits of rock.
7. Leaves lose water vapor through (*a*) the stems (*b*) tiny pores on both upper and lower surfaces (*c*) the rough edges.

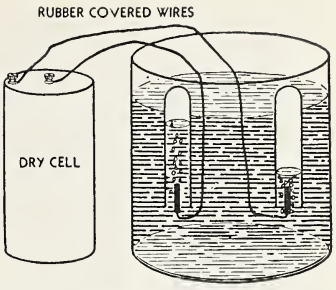
——Science activity for fun——

Weigh some dried fruit. Soak it in clear water until it will take in no more. Weigh the fruit again. Note how much it increased in size. If you are careful in doing the experiment, it would be safe to test the fruit by eating some to learn if the water makes the food easier to eat.

2. Just what is water?

Water covers more than three-fourths of the earth's surface, and it is so much a part of our surroundings that we

may be surprised by the question "What is water?" Yet if we try to define it, we may discover that we really don't know as much about it as we may think. Usually we end up by describing its uses. But how water is used depends upon what it is and what it can do. Let us see if we can discover enough about it to answer our questions.



This drawing shows the important parts of the apparatus needed to break water into oxygen and hydrogen. To make the process work faster, larger cells are used and the tubes are usually held by clamps.

Of what is water made? We know that water is not a simple substance. It is a compound containing two elements. One of these is oxygen, which we have already learned is that part of the air which supports burning. The other is an element called hydrogen. It is the lightest gas known, and is dangerously explosive when mixed with air and set off by a spark or flame.

Water may be decomposed [dē′kŏm·pōzd′, separated into its elements] by passing an electric current through it. To do this it is necessary only to place two carbon rods in water and insert them in inverted test tubes which have been previously filled with water. The rods are then connected to three or four dry cells by means of wires which should be covered by a waterproof material. Since pure water will not carry an electric current, it is necessary to add some substance to it which will help the current through the water. Sulphuric acid [sŭl·fū′rĭk ăs′ĭd, a strong, sour, dangerous chemical] will do.

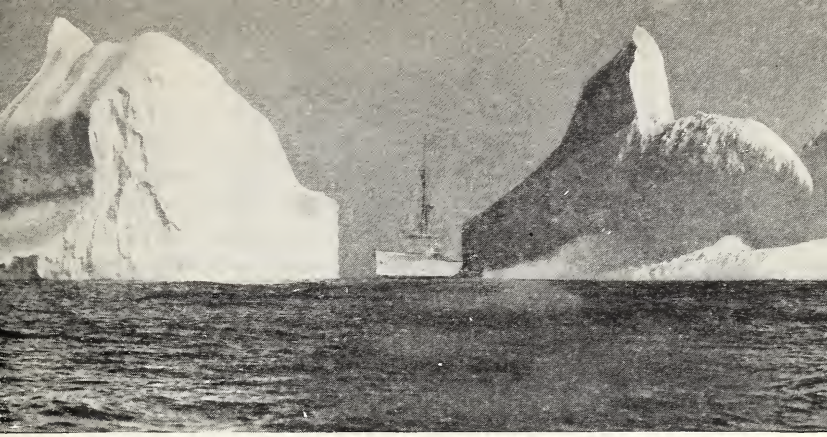
As the current flows from the dry cells, bubbles rise from each carbon rod and enter the test tubes. The tube containing the largest amount of gas has hydrogen in it. The other one contains oxygen. Because there is twice as much hydrogen as oxygen in the water, chemists say that the correct

Toy balloons are inflated with hydrogen. How do you know that some other gas is not being used? Are toy balloons safe to play with around lighted cigarettes?

formula [fôr′mū·là, an expression that shows by symbols the chemical elements of a substance] for water is H_2O. This means that there are two parts of hydrogen for each part of oxygen.

How does water change its form? If water is cooled sufficiently, it changes to ice. Ice is really solid water and always has a temperature of 32 degrees or less. It has the same amounts of hydrogen and oxygen in it as has the water from which it was formed. It is also odorless and tasteless, although it may take up odors of other things rather readily. It is perfectly dry instead of wet, and it will remain that way as long as the temperature is kept below 32 degrees. Above 32 degrees some of the ice on the surface will change back to water. While water always takes the shape of the container, ice keeps whatever form it happens to have.

If a gallon of water freezes, it makes almost $1\frac{1}{10}$ gallons of ice. A gallon of ice, then, weighs less than a gallon of water. Ice floats in water because it is lighter in weight than water.



Courtesy U. S. Coast Guard

Compared to the boat, the iceberg seems huge, but still only a small part is visible. Icebergs are a source of danger to boats which may crash into them in the dark.

The expansion of freezing water produces some interesting changes. If water is allowed to freeze in a steel pipe, or in a can which has a narrow mouth, the expansion bursts the metal as if it were paper. If a bottle of milk is left out of doors where it can freeze, the milk pushes up the cap of the bottle, and may project more than an inch above the top of the bottle.

Ice forms icebergs which float in the ocean. An iceberg is really 10 times as large as it looks, for nine-tenths of the iceberg is under water.

Ice is useful in a number of ways. It contains less heat than does water, and when heat is added to it, it changes back to water. If we put ice into tea, the heat from the tea goes into the ice, melting the ice and cooling the tea. Ice is used for keeping foods cool, for cooling drinks in summer, and for cooling buildings. The difference in the amount of heat that ice and water contain at 32 degrees is the most important difference between them. Is heat taken in or given off by melting ice?

Water vapor, like ice, is a form of water. It is a gas that is invisible and is impossible to keep in a container unless the

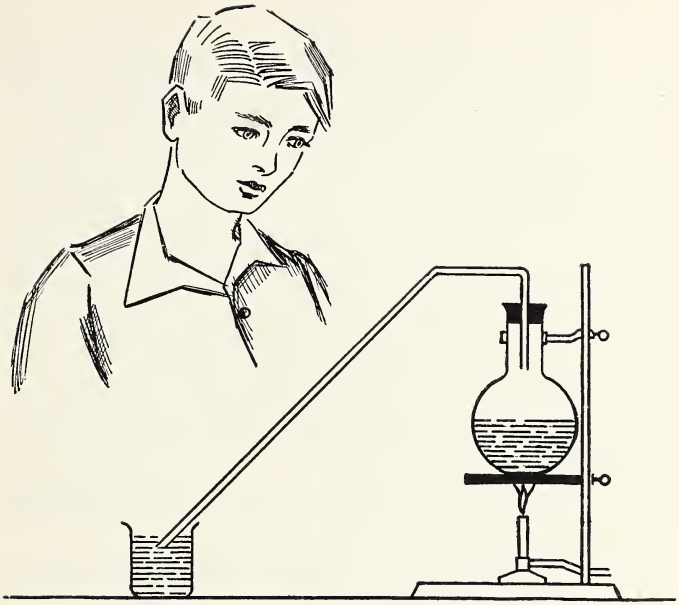
container is tightly closed. The natural escape of water vapor from the surface of the water is called evaporation [ē·văp′ō·rā′shŭn]. The rate of evaporation increases until the water boils. This normally occurs at 212 degrees at sea level, and as long as there is any water left the temperature will remain the same. Most of the water vapor in the air is formed by slow evaporation, for there is little boiling water in natural conditions. In a few places in nature we find boiling water.

When water evaporates, the vapor rises from the surface of the water. Heat is taken in from the air and from the surroundings. You can test this fact by wetting your finger and blowing on it. You can feel the heat leaving your finger as the water evaporates. When water boils, it evaporates very fast, forming bubbles in the water which are filled with steam. Much heat is required to boil water.

What are the uses of steam? A gallon of water makes enough water vapor to fill a fair-sized closet. However, the vapor changes back to water unless it is kept quite warm. When water vapor is hotter than 212 degrees, it is sometimes called steam.

When a container filled with steam is cooled, the steam condenses. The water formed takes up little space, and leaves the container almost empty. If there is an opening in the container through which air can enter, it fills the space. If the opening is closed, the space in the container becomes a partial vacuum [văk′ū·ŭm, a perfectly empty space without even air in it].

The vacuum formed by condensing water vapor can be used to fill a boiler. The water in the boiler is brought to a boil, forcing out the air and filling the upper part of the boiler with steam. A pipe from the top of the boiler is run into a tank of water, and the boiler is left to cool. As the boiler cools, a partial vacuum is formed, and air pressure pushes water from the tank up the pipe and into the vacuum, filling the boiler with water. In this way it is possible to save the expense of buying pumps to fill small boilers.



This diagram shows how to set up the apparatus for the demonstration.

Boilers are used to make steam for running many types of steam engines. Steam in an engine expands with enough force to push against and move the parts of the engine, and to do work.

Water vapor differs from water because it contains more heat than does water. Steam differs from water vapor in that it is much hotter.

Demonstration. What Are Three Forms of Water?

What to use: Ice, flask, burner, ring stand, one-hole stopper, glass tubing, beaker.

What to do: Clamp the flask on the ring stand, and arrange a delivery tube to the beaker, as shown in the

drawing. Put the ice in the flask and melt it slowly Examine the water formed. Boil the water so that steam bubbles into the water in the beaker. Leaving the delivery tube under water in the beaker, withdraw the burner, and let the boiling flask cool.

What was observed: Is the water formed when ice melts different in any way from other water? Does the steam drive air from the flask? Do bubbles of steam escape from the beaker, or change to water and disappear? What happens to the steam when the water runs into the flask? Which would take the longest time—to melt the ice, to boil the water, or to boil away the water in the form of steam?

What was learned: Select the correct conclusion.

(*a*) Ice melts and lowers the air pressure so that water runs into the flask.

(*b*) The three forms of water are ice, water, and steam; and the form depends upon the amount of heat they hold.

(*c*) When steam is formed, water runs into the flask because water is heaviest.

——Things to think about——

Write the numbers from 1 to 10 on a piece of paper or in your notebook. The first list contains the subjects of sentences, the second list, the predicates. Match the subjects and predicates. Write after the number of the subject the letter of the predicate which makes a true statement.

Subjects

1. H_2O
2. Hydrogen
3. Oxygen
4. Ice
5. Heat
6. Water vapor
7. An electric current
8. Adding heat to water
9. Water
10. The temperature at which water boils

Predicates

A. is used to separate water into gases.
B. is the chemist's way of writing water.
C. causes it to change form.
D. is 212 degrees.
E. must be added to or taken from water to change its form.
F. is formed when water evaporates.
G. expands when it freezes.
H. is the gas in which hydrogen burns to form water.
I. is the solid form of water.
J. is a lightweight, explosive gas.

——Science activity for fun——

Carefully drop a fairly large piece of ice into boiling water to see what happens. Does the ice float?

3. How does water make some things disappear?

If you add some table salt to water a little bit at a time and stir or heat the water, the salt will disappear. When you taste the water, you recognize by the flavor that the salt has been scattered through the water. Many things are acted upon by water in this manner. The ability of water to take up materials in this way makes it one of the most important substances known.

How do substances dissolve in water? Scientists have studied the process of dissolving substances in water a great deal, but they have been unable to find direct proof of the method by which it takes place. They believe that a substance must divide into very small particles before it can be taken up by the water. These particles are then scattered evenly throughout the water, since a sample taken from any part of the liquid will contain the same amount as any other sample. This process of causing materials to divide into very small particles and disappear in the liquid is called

Brown photo

All the material of which these terraces are made came dissolved in hot water from underground. As the water cooled, it left behind the material which formed the beautiful rocks. You can see this terrace in Yellowstone Park.

dissolving. After a substance has been dissolved, the resulting mixture is called a *solution.*

Water which is free of dissolved materials is said to be pure water. Pure water is difficult to obtain, since nearly everything dissolves in water to some extent. The presence of some things in water is not necessarily bad, for many things will not harm us.

Does drinking water contain dissolved materials? Water which is found out of doors, untreated or undisturbed by man, is called natural water. Such natural water flows in the streams or underground, or is found in lakes and oceans. Since it is constantly in contact with substances in the soil, it is certain to contain dissolved materials. Everyone knows that the sea is salty. The water has dissolved the salt from the earth and carried it out to sea.

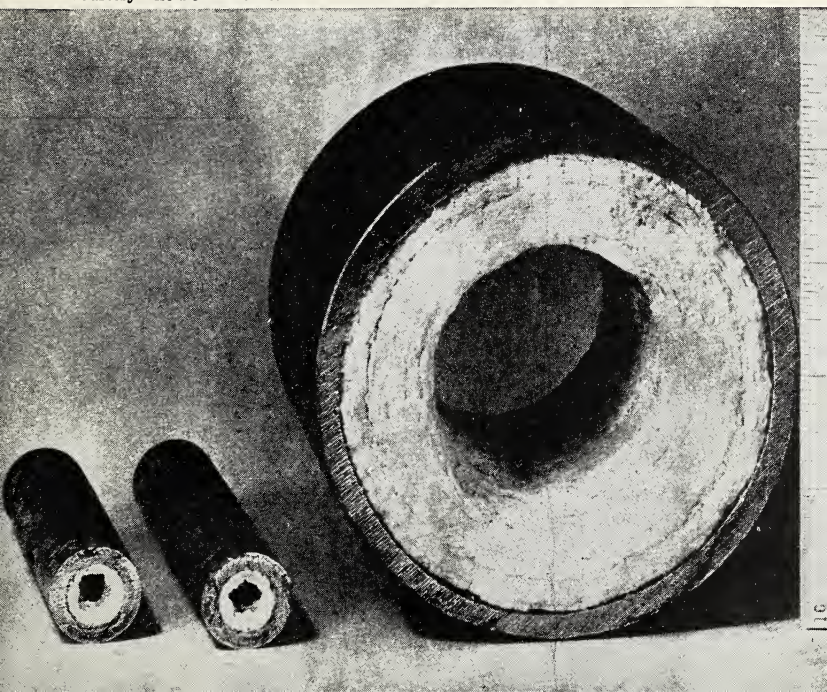
If rain water is not carried off by streams and rivers, it may soak into the ground and collect in layers of sand or

broken rock deep in the ground. If it remains in contact with the earth long enough, some of the less easily dissolved earth materials may be taken up by the water just as the salt was dissolved.

You can test well water or city water for dissolved substances by allowing some to evaporate in a perfectly clean glass dish. Nearly all drinking water will leave a deposit on the sides and bottom of the dish after the water is gone. The most common substance found in water is called lime. You can tell lime by the fact that bubbles of gas will rise from it if hydrochloric [hī′drō·klō′rĭk] acid is added to some in a test tube. Try this with some of the scale taken from your teakettle at home. Teakettle scale comes from water and is left behind as the water boils away.

Minerals dissolved in water are readily deposited in pipes. Is it any wonder that in old pipes water runs slowly when there is scarcely any opening left in the pipe?

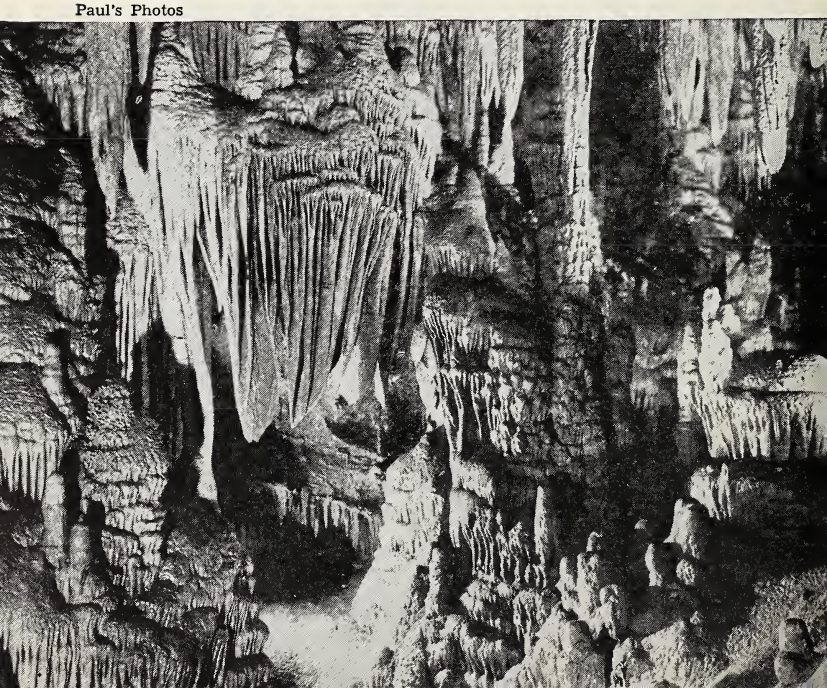
Courtesy The Permutit Co.



How does lime get into water? Rain water contains no dissolved solids, but it may dissolve some of the gases of the air as it falls. One of the gases dissolved is carbon dioxide. Limestone rock dissolves in water very slowly. However, if the water contains enough dissolved carbon dioxide, the limestone will dissolve rapidly in it. Sometimes very large caves are dissolved out of limestone rock by such water. Mammoth Cave in Kentucky was formed in this way, and it is continually being enlarged by this action. Of course this process takes a very long time, but processes which take place in the earth have had a very long time in which to work. If 50 or 100,000 years are needed, there is easily that much time, since the age of the earth may be reckoned in billions of years.

It is easy to believe that water contains mineral when it can dissolve enough stone to form a huge cave! This is part of the Luray Caverns of Virginia.

Paul's Photos



Courtesy Alberta Government.

Irrigated farms require drainage as well as irrigation in order to prevent too many dissolved minerals from being left as the water evaporates. This picture was taken in Southern Alberta.

Hot water dissolves many materials much faster than does cold water. When the water cools, the substances are deposited. Among the most interesting sights in Yellowstone Park are the terraces, built of materials dissolved from the rocks underground, and brought to the surface by hot water.

How are plants affected by this power of water? Plants depend upon water to dissolve minerals from the soil and carry them to the leaves. Without this service, plants could not live and soon there would be no other life on the earth. If the soil contains too much of these substances, the plants may not be able to live. In certain places the water which flows over the rocks is cut off from the sea, so that the water can evaporate only from the land. Such land becomes salty or alkaline [ăl′kȧ·līn, a name applied to bitter, saltlike substances], depending on the nature of the dissolved chemicals. Plants cannot live in land that is alkaline. Salty areas and alkaline plains are found in the western deserts.

Where land is irrigated [ĭr′ĭ·gāt′ĕd, supplied with water from ditches] the air is dry, and the water evaporates, leaving behind the dissolved substances. The land may finally become so full of salt that it is necessary to run more water on the land and drain it away in order to get rid of the extra salt. Does it seem strange to you that it should be necessary to drain irrigated land?

Can water carry solid particles? Very often water may remove from the land materials that are not actually dissolved. Such materials will remain suspended in water as long as it keeps moving. If a sample is collected and allowed to stand, the particles will settle out, leaving clear water. You can try this with some muddy water.

Materials dissolved by the water, however, will not settle out no matter how long you let the water stand. If the water were allowed to evaporate, what would happen?

Are dissolved materials in water harmful to us? The dissolved materials found in city water and in well water are generally not harmful. However, water obtained in some places may contain certain minerals [mĭn′ẽr·ălz, compounds occurring naturally in the earth's crust] that are harmful.

Some springs contain so much dissolved mineral that their water is poisonous. These springs are found almost entirely in desert regions, or in regions where there is some unusual kind of rock.

Some sick people take the "water cure" by drinking the water from springs containing certain minerals. Sulphur gas, iron, or carbon dioxide are usually dissolved in such waters. As far as is known, these waters do not cure anything, although people may get well while taking the "cure" because they rest, drink plenty of water, and eat and exercise properly. All these are desirable habits which they probably have not been practicing.

There are many mineral springs in different parts of the United States. Is there one near your home?

Demonstration. Does Water Have Mineral in It?

What to use: Tap water, beaker, ring stand, burner, watch glass or glass plate.

What to do: Put some water in the beaker, and place it over the burner on the ring stand. Over the top of the beaker place the watch glass or any piece of clean glass. Put a few drops of water on the glass, and heat the water in the beaker until it is boiling. The steam will then heat the glass. Dry the underside of the glass, and hold it toward the light.

What was observed: Can you see a ring of white, saltlike material on the glass?

What was learned: Select the correct conclusion.

(*a*) Minerals on the glass condense from the steam.

(*b*) When water is evaporated, mineral matter is left behind.

(*c*) Heating water on glass dissolves out the salt in the glass.

——Things to think about——

Write the numbers from 1 to 9 on a piece of paper or in your notebook. Opposite each number write the letter before the word or group of words which best completes the sentence.

1. A liquid containing a dissolved substance is called a (*a*) solution (*b*) mixture (*c*) suspension.
2. If bubbles rise from teakettle scale when acid is put on it, the scale contains (*a*) salt (*b*) limestone (*c*) rock.
3. Material which makes up scale is from the (*a*) kettle (*b*) air (*c*) water.
4. The materials which form the Yellowstone terraces were (*a*) dissolved by hot water (*b*) dissolved by gases (*c*) washed up from volcanoes.
5. When soil has a large amount of a certain mineral in it, it is (*a*) alkaline (*b*) dry (*c*) fertile.

Courtesy Boy Scouts of America

It is better to be safe, though thirsty, than sorry. These Boy Scouts waited to get a drink until they came to a spring that provided safe water.

6. Materials in water which are not dissolved will (*a*) float (*b*) disappear (*c*) settle out.

7. The most common substance found in well water is called (*a*) salt (*b*) a chemical (*c*) lime.

8. Rain water contains (*a*) a large amount of lime (*b*) hydrochloric acid (*c*) no dissolved solids.

9. Materials dissolved in water will (*a*) not settle out (*b*) leave no traces if the water is allowed to evaporate (*c*) be seen if the water is closely examined.

——Science activity for fun——

1. Fill one cup three-fourths full of water, and another three-fourths full of salt. See how much salt you can dissolve in the water. When the water will hold no more salt, see if it will dissolve soda.

4. How can water keep us well?

A certain mining city in the East obtained its water supply from a spring-fed mountain stream which had always been very pure. Suddenly hundreds of people became sick, and many died from a serious disease carried in the water. Health authorities discovered that a family living far out of the city was emptying its waste materials into this stream. When this cause of the disease had been removed, the doctors were able to get it under control and people began to get well.

This true story shows the importance of drinking pure water. However, good health demands also that we keep

clean and remove dangerous wastes. Water is necessary for both.

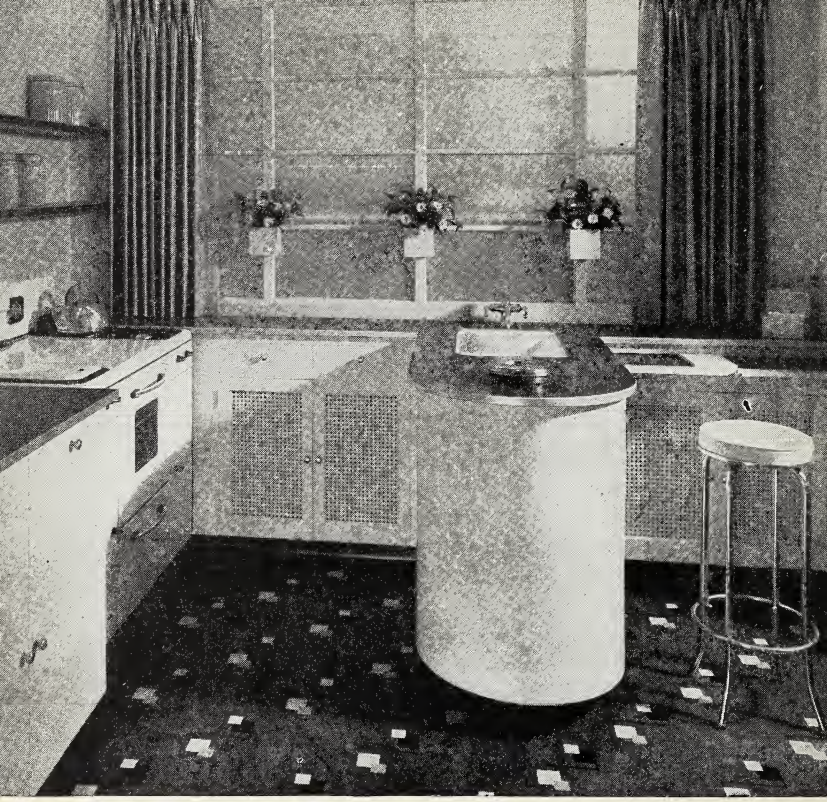
How can we purify water? Large-city water systems remove germs that cause disease by a process which would be too difficult and too expensive to use at home. If you live on a farm or go camping, you will need a method for purifying water to make sure that it is safe to drink. Even large-city water systems can be put out of order during flood conditions. It is important, then, for everyone to know how to obtain wholesome water. Wholesome water is water that is free from germs which might cause disease.

The simplest way to purify water is to boil it. Boiling water for 20 minutes will kill practically all common germs. Boiled water tastes flat because boiling drives off the air in water. Water can be made to taste good after boiling by shaking it in a jar with air. The containers in which the boiled water is to be kept should be cleaned by boiling before storing water in them.

If you must drink water which may be unsafe, it can be purified by putting several drops of ordinary iodine in each pint of water. The water should stand for 15 minutes before it is used in order to give the iodine time to kill the germs. It is entirely safe, for a few days, to drink water treated with iodine. Over a period of months or years, harm may result from the iodine, but this is not known. Certainly the risk from iodine is much less than the risk from typhoid fever, which is the disease most often carried by water.

How is water used to remove wastes from the house? Less than 100 years ago, it was common for people even in large cities to throw dishwater, garbage, and household wastes into the streets or in the backyard. There the waste decayed, attracted flies, and spread disease. This practice is still found in poorer sections of some cities and on some farms.

Our cities today are safe and clean, largely because we have learned to use water to carry away our wastes. Nearly every city has a complete sewage system. In many places



Courtesy Congoleum-Nairn, Inc.

The sink is the center of many important kitchen activities—preparing vegetables, obtaining water for cooking, washing dishes, and many others. This sink is conveniently located.

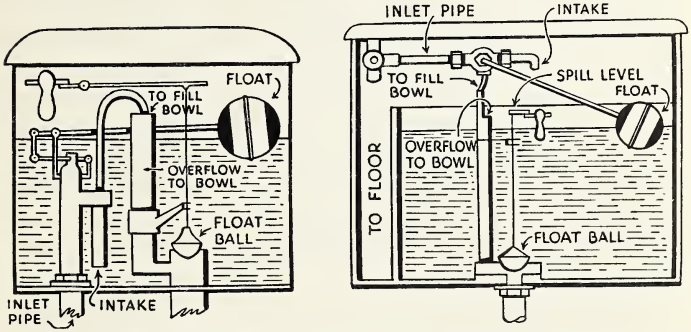
the waste is dumped into rivers or streams, but modern systems use sewage-disposal plants to make sure that the streams are not made unfit and even unsafe for use by others. Sufficient water is kept flowing through the sewers to carry all wastes away, and from time to time the sewers are flushed by powerful streams of water.

People living on farms or in other places far from a regular sewage system can have safe methods to dispose of sew-

age. Wastes can be carried away from the living quarters by pipes which lead to cesspools. Cesspools are shallow wells which permit the water to drain away. Chemicals, which can be obtained very cheaply, are added to the waste in the cesspool to aid in its decay and to destroy germs.

What devices are used in houses to remove wastes? Although some houses do not have one, the kitchen sink provides the quickest possible method of getting rid of dishwater and waste liquids in the kitchen. It should be connected to a pipe leading away from the house, and a supply of water should be available to wash away waste materials. Cleanliness in the kitchen is especially important because there food is prepared and dishes are cleaned.

The opening through which water runs from the sink is usually covered with a strainer to keep materials from clogging the pipe. The pipe under the sink is bent like the letter *S*. This bend is the trap. Where the pipe goes into the wall, the trap is shaped like the letter *P*. The trap is shaped to hold a quantity of water to prevent sewer gas from entering the house. The trap may catch coffee grounds, lint, match sticks, cloth, and other materials which clog the pipes. It



The float opens and closes a valve like the one in a faucet to let water run into the tank. The tank at the left is unsafe because connections from the city water pipe are under the dirty water of the tank. Water flows safely into the other tank from above.

Courtesy Crane Co.

A modern, sanitary bathroom should be a part of every home. This bathroom is especially convenient. Note that the tub has a shower and a safety bar to hold to prevent falls.

should be cleaned out whenever the water does not run out well.

The bathroom washbowl and bathtub also are provided with traps. There should be a plug at the bottom of the trap which can be removed when the trap needs to be cleaned. There often is a pipe which runs from the sewer connection up through the roof to permit sewer gases to escape.

The toilet flush tank is a clever device for supplying a large amount of water for carrying away human body wastes. Body wastes are the greatest carriers of disease germs.

The flush tank is a box lined with metal or made of chinaware. It has a float-controlled water valve which permits water to flow into the tank when it is empty, but which closes when the tank is full. There is another valve which opens a pipe leading from the tank to the toilet. This valve is a pear-shaped rubber ball. When the tank is flushed, the rubber ball is lifted up and floats on the water until the water runs out. The ball drops into place when the tank is emptied, and water runs in slowly enough that the ball is pressed down before there is enough water to float it.

The pipe which brings water into the tank should be above the water so that water from the tank cannot run back into the pipes. Dirty water causes disease.

Another chance of making water unsafe may result from using a sprayer hose in the bathtub. If the hose is in the

bath water and the water is shut off from the house, the water in the tub may "suck back" into the pipes through the open faucet. Bath water is not safe to drink.

How does water help us keep clean? Because water will dissolve many things, it is very valuable in washing. To aid water, soaps or cleaning powders are often used. Unless they increase the number of things which can be removed by water, they have little or no value, and the soaps and powders must do this without harming the skin or cloth.

To aid in keeping the body clean, a tub with running water or a shower is a great convenience. A shower may be installed in the basement or a shower cabinet may be obtained for the house for very little money.

You may have seen water wagons going along city streets early in the morning, washing litter into the sewer openings. This is one of the many ways in which cities are dependent upon water for cleanliness. Water carries the sewage which runs from houses to places where it is purified and carried away. People use hoses to wash sidewalks and yards. Soot is cleaned from the walls of houses by water.

How does water add to our enjoyment? One of the important uses for water is for swimming. The sport provides pleasure and exercise, although many people are drowned each year. If properly conducted, swimming is entirely safe. Swimming is one of the few ways most people can get relief from the intense summer heat. It would be ideal if every city lacking natural bathing beaches provided some kind of swimming accommodations within walking distance for every child. Country dwellers by working together can clean small beaches wherever natural water is available. A lifeguard, or a grownup with a rowboat, should always be near to supervise swimming.

Other pleasures water offers are rowing, canoeing, and sailing. However, unless you have been taught the proper use of boats, you should not undertake these sports.

Practically everywhere in Canada water freezes in the wintertime and provides places for ice skating. It is dan-

gerous to skate over rivers, ponds, or lakes until older people have tested the ice to be sure that it is strong enough.

Demonstration. How Does the Trap of a Sink Work?

What to use: Large-bore glass tubing, rubber tube, funnel, soap, oil, beaker, burner, fine soil.

What to do: Bend the glass tubing in a flame to make a trap like an *S,* which is the usual shape of a sink trap. Connect the trap to the funnel with a short rubber tube, and hold it over a beaker. Pour water into the funnel. Pour some oil into the funnel. Pour some soapsuds mixed with oil into the funnel. Sift some fine soil into the funnel, and wash it down.

What was observed: Does the trap seal up the pipe? How does a trap become clogged?

What was learned: Select the correct conclusion.

(*a*) Water in the trap keeps foul air from flowing up the pipe, but the trap may be clogged with dirt.

(*b*) Because traps hold so much dirt, they should not be used.

(*c*) Dirt in the sink can be washed away with water.

——Things to think about——

Write the numbers from 1 to 8 on a piece of paper or in your notebook. The first list contains the subjects of sentences, the second list, the predicates. Match the subjects and predicates. Write after the number of the subject the letter of the predicate which makes a true statement.

Subjects

1. Boiling water for 20 minutes
2. Iodine
3. A sink
4. A flush tank
5. Cleanliness
6. A trap
7. When we swim, we
8. A city water system

Eugene Rosing photo

One of the important uses of water is for enjoyment. Many of our most pleasant moments and the most beautiful scenes are associated with water. How many of your sports and games depend upon water?

Predicates

A. is an *S*-shaped pipe beneath the sink.
B. use water to keep cool.
C. makes it safe for use.
D. should provide us with a pure water supply.
E. is an automatic device which holds water.
F. depends upon water.
G. is necessary in a convenient kitchen.
H. is a chemical which kills germs in water.

——Science activity for fun——

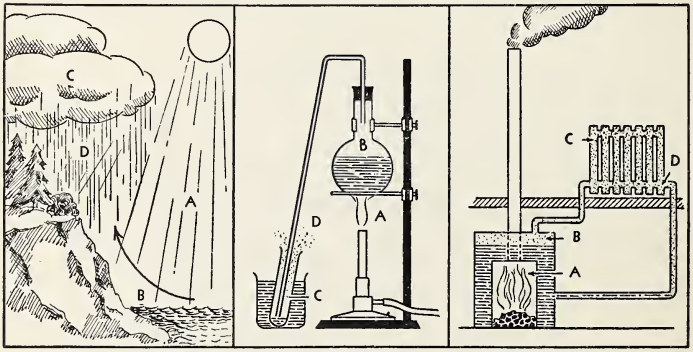
Find out how the rubber cup on the end of a stick is used to open clogged drains.

5. Of what use is the water cycle?

You have seen how year after year rain falls on the land, the land becomes dry as the water evaporates or runs to the ocean, rain falls again, and again the land becomes dry. Changes in the form of water—from invisible vapor to clouds, then to rain, and back to vapor—provide water necessary for life. Water vapor in the air, although it is dry, prevents living things from drying out. Are there other ways in which we benefit from the changes in the form of water?

What is the water cycle? Water changes to water vapor only when heat is added to it, and water vapor changes back to water only when it is cooled. Water in an open dish is changed to a gas only when it takes heat from the air. The air loses as much heat as the water gains. Then when the water vapor is cooled, it gives off heat to the air, and changes back to water. These changes make up the *water cycle,* or *circle.*

Water evaporates more rapidly when heat is added. Thus if a dish of water is placed in the sunshine, it evaporates more rapidly than does water left in the cool shade. Water in a kettle on a hot stove changes to vapor rapidly, because



These drawings show the water cycle operating under different conditions, but going through the same steps in each case. At *A* heat is supplied; at *B* water changes to vapor; at *C* cooling takes place; and at *D* water vapor changes to water.

molecules [mŏl′ē·kūlz, smallest particles that are still like the whole] of water move more rapidly when they are heated than before. Some molecules gain enough energy that they escape from the liquid into the air. When water is heated to 212 degrees at sea level, so many molecules gain energy that they push the water aside to form the bubbles seen in boiling water. These bubbles are filled with molecules of water vapor and rise to the surface, permitting the molecules to escape into the air. When water is heated on a stove, the water is heated only as much as the stove is cooled.

In your everyday experience you have noticed that evaporation cools the surrounding objects. When you sit on the beach in a wet swimming suit, you become cool as the suit dries. You know, too, that water vapor condensing on a cool surface warms the surface. A glass of ice water becomes warmer as drops of water form on its sides.

Is there a natural water cycle? The sun supplies energy outdoors to evaporate water from the surface of the ocean, from moist soil, from lakes and rivers, from plants, and from many smaller sources of water. Water vapor—a dry, invisible gas—remains part of the air until it is cooled. Cooling usually takes place when water vapor is carried into the upper air by the wind. The upper air is almost always cooler than the air near the earth. When water vapor gives off its heat, it changes back to water drops to form clouds from which rain or snow may fall. Sometimes water vapor may form fog or dew as it cools.

Because of the movement of the winds, rain usually falls at some distance from the place where the water vapor was formed. This is fortunate, for water evaporated from the ocean falls upon the land, making life possible.

There is a great difference between the water of the ocean and rain water. Ocean water is bitter and salty. Rain water is fresh and without minerals. Because water vapor does not contain minerals, it condenses to form pure water. Ocean water, on the other hand, contains many salts dissolved by water running from the land, and is never pure.

Paul's Photos

Formation of fog is part of the water cycle in nature. The water vapor carried by the air is cooled, and changes to tiny drops of water. The drops are so small that they fall slowly. Fog often forms in mountain valleys and along the seacoast.

How does the water cycle affect us in our homes? When a kettle boils on the stove, vapor passes into the air. The vapor may form the tiny drops that are visible for an instant just above the kettle, but air currents carry them away. Soon the drops are evaporated and again taken into the air. The water vapor is carried by air currents against the windows, and on cold days the heat carried by the vapor is given off to the cold glass. The vapor changes to drops of water which collect on the glass. If the window is very cold, frost may form.

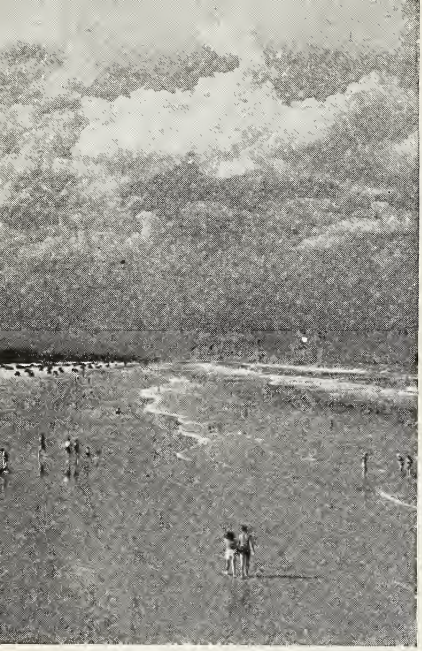
Because water vapor condenses on cold windows, it is difficult to keep the air in a room moist enough for comfort in winter. When the air is dry, water evaporates rapidly from

the skin and throat. Because heat is absorbed from the body, we feel cool and are inclined to heat the house to a higher temperature in order to be comfortable. This results in a waste of coal, since a temperature of 68 to 70 degrees is sufficient if the amount of water vapor in the air is kept high enough. A few pans of water or a number of potted plants will help maintain better living conditions. Some furnaces may be equipped with special devices to evaporate water.

Is there a water cycle in a steam heating system? A steam heating system consists of a furnace and a boiler, pipes, and radiators. Water in the boiler is heated by a fire in the furnace, and the steam formed passes up the pipes to the radiators. The heat of the furnace fire causes water to change to

When water vapor changes back to water, we put on our raincoats, the sky seems to drip, the clouds threaten, and we hurry.

Harold M. Lambert photo



Courtesy Daytona Beach Chamber of Commerce

A sandy beach is always attractive. Here the sand is so tightly packed that cars can drive on it at low tide. The clouds are made up of fresh water that came from the salty ocean. How could they?

steam, which is water vapor heated above 212 degrees. The steam gives off its heat when it comes into contact with the cold radiator. The heat passes through the iron of the radiator, and is carried into the room. The water formed as the steam condenses trickles back down the pipe, and runs into the boiler. Here again we have the four steps of the water cycle.

What is meant by distillation? Distillation [dĭs′tĭ·lā′-shŭn] is a way of using the water cycle to purify water. The water is boiled, and water vapor passes through the delivery tube into the test tube. When the vapor touches the glass test tube standing in cold water, it changes back to water.

Water which is distilled is definitely purer than any other kind of water. All the solid materials are left behind, just as they are in a teakettle in which crust forms. These solid materials may be seen on the glass flask if distillation is continued for a long time.

The four steps of the water cycle in distillation are exactly the same as in nature. Heat must be added to the water. The water evaporates. The heat is given off. The water condenses.

There are many uses for which water must be absolutely pure—not only free from germs, but free from minerals and even dissolved gases. For example, distilled water is gen-

erally used in automobile storage batteries because ordinary water contains chemicals which destroy the strength of the battery.

DEMONSTRATION. HOW IS WATER DISTILLED?

What to use: Flask, burner, ring stand, one-hole stopper, glass tubing, beaker, test tube, ink.

What to do: Set up the apparatus as shown in the drawing on page 152. Put cold water in the beaker. Put ink in the water in the flask. Boil the water in the flask, and watch the apparatus.

What was observed: What collects on the flask when water is first heated? How is the water in the test tube different from that in the flask? Where does the heat go which is carried down the tube by the steam?

What was learned: Select the correct conclusion.

(*a*) Distilled water is formed by cooling steam.

(*b*) Distilled water must be made from water containing ink.

(*c*) Rain water is as pure as distilled water.

——Things to think about——

Write the numbers from 1 to 10 on a piece of paper or in your notebook. Complete the following sentences to make true statements. Opposite each number write the word needed to complete the sentence.

The change from vapor to water, and from water to vapor, in nature is called the water —1—. For water to evaporate, it must take in —2—. For water vapor to condense, it must give off —3—. When salt water evaporates, the —4— is left behind. When water is heated in a flask, and the vapor is caught and cooled, the process is called —5—. Air containing —6— is lighter than dry air. When water boils, it gives off —7—. Frost on cold windows is made from —8—. During winter the air in our homes is usually too —9—. —10— air causes water to evaporate more quickly from the body.

——Science activity for fun——

Explain how the water cycle works in a steam-heating system. Make a drawing on a poster, similar to those shown on page 152, to explain your conclusions.

6. How does water help us do work?

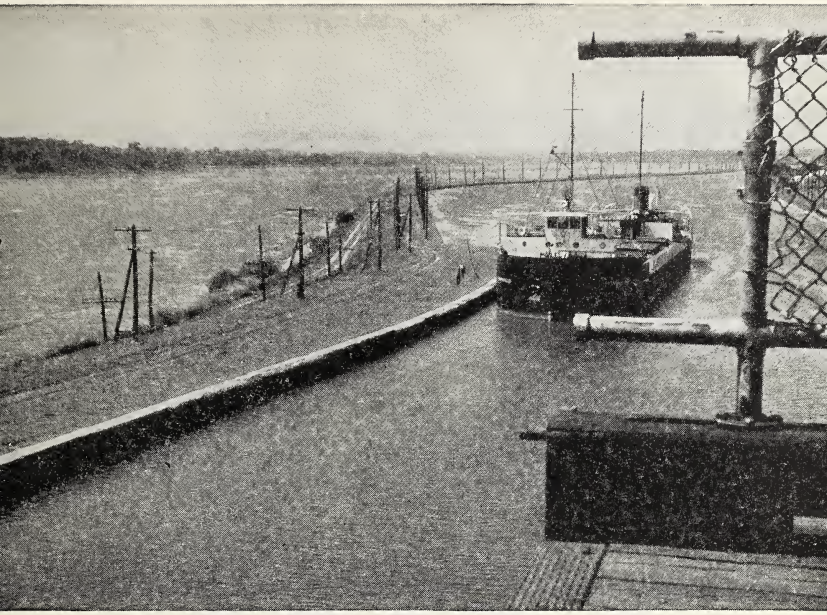
When water is in the vapor state, it is lifted to higher levels where it cools and falls back to the earth's surface. Since water tends to return to its own level, it then begins to run down the hills to the valleys where streams are formed. As it moves from this level to lower points, it is capable of doing work, just as a block of iron which is made to fall repeatedly on a large sharpened post will do work by driving the post into hard earth.

Many water wheels are still in use in the United States. This wheel, which is made of steel, is 30 feet in diameter and provides power for the mill. The water has been shut off so that you can see how the cups on the wheel are arranged.

Courtesy Fitz Water Wheel Company

Since many things will float on the water, its continual flow to the sea can be used to carry burdens. Lumbermen are able to move great rafts of logs from the forests to the mills, and boats can be carried to all parts of the world.

How do rivers provide power? As water returns to the ocean to complete the water cycle, it often falls many feet between its starting place and the ocean. The greater the fall, the greater is the



Courtesy Ontario Dept. of Travel & Publicity.

Water is of great value in transporting heavy goods at low cost. To overcome the Longue Sault Rapids of the St. Lawrence, a canal was built near Cornwall.

force which the water possesses. This force can easily be put to work by directing the water against water wheels. The water wheel has many paddles on which the water falls. The weight of the water on the paddles or blades causes the wheel to turn. The wheel is fastened to a shaft which is used to turn other machinery.

The oldest water wheels in Canada were used to grind wheat for food. Other water wheels were used to turn the saws which cut boards for the first homes built of lumber in Canada. Still others were used to operate spinning and weaving machinery.

Today water wheels are very much improved. They are made of steel and are enclosed in metal cases to keep the water from sliding off the sides of the blades. Generally they are used to generate or develop electric current, al-

Photo by U. S. Forest Service

Water provides the most economical means of transporting logs to mills where they are made into lumber. These men are separating the small and large logs for different uses.

though sometimes they are used for power. One of the largest flour mills in the United States still uses a water wheel.

If there were no water cycle, the water would not return to higher levels, and we would soon use up the water in the streams and lakes. As it is now, man is using but a small part of the available water power.

Why does a boat float? If you place a piece of iron in water, it will sink, yet most boats that carry freight or passengers are made of iron. Do you know why a boat floats? Wood floats because it is lighter than water. That is, a block of wood one foot on a side weighs less than that amount of water. A block of iron of the same size would weigh nearly eight times as much as the water, and it would sink. However, if we were to build a tight box of iron one foot on a side, it would weigh less than a cubic foot of water. Such a box of iron would float.

As our iron box sinks, water will be forced out of the way. The level of the water will be raised. Since water has weight,

it will begin to press against the box. When enough water has been displaced to equal the weight of the box, it can sink no farther. If weights are added to the box, it will settle deeper in the water.

Put a pan or cover of a tin can on water with the open side up. Does the pan float? Pour some sand in the pan. It still floats until enough weight is added to force the edge below the water surface; then it quickly sinks. If you place the empty pan edgewise on the water, it sinks immediately. Can you explain why boats are limited to a certain number of passengers or amount of freight?

How is water used for transportation? The only difference between our iron box or pan and a boat is that the boat is shaped so that it will move easily through the water. Transportation by water is the cheapest of all methods, but it is also the slowest.

There are several kinds of freight which could hardly be moved long distances except by water without increasing the cost too much. Iron ore mined on the north shore of Lake Superior is shipped on ore boats across the Great Lakes to the steel mills of Ontario and the United States. Another product shipped best by water is wheat. Some wheat is shipped down the St. Lawrence to Montreal, where it is reloaded on boats that cross the ocean. Where possible, coal is shipped by water.

The use of rivers for transportation is less common today than it was many years ago. Railroads are faster and, for handling most products, nearly as cheap. Although airplanes now cross oceans, boats are still the only method of shipping our exports to other parts of the world. Mail and light packages can be shipped by air if speed is essential, but farm products and manufactured goods must depend upon the slower boats to reach their markets.

How do oceans serve us? The ocean is 97 per cent water and 3 per cent dissolved solid materials. Most of the solid material is salt, but every chemical found on the surface of the earth is dissolved to some extent in ocean water. There

is even a considerable amount of gold in the ocean. If there were some cheap way of getting such things from ocean water, there would be no need of mining the crust of the earth at all. The principal things obtained from the ocean waters now include salt, bromine (brō′mēn), and magnesium (măg nē′ shĭ ŭm). Bromine is used in making "anti-knock" gasoline and photographic films. Magnesium is used in bombs because it burns with a hot flame, and is used in making objects requiring a lightweight metal.

The tides make the ocean interesting. Between the times when the tide is high, there is a period when the water is low. During high tide larger boats can enter shallower harbors than would be possible if the water stayed at the same level all the time.

DEMONSTRATION. DO OBJECTS WEIGH LESS IN WATER THAN IN AIR?

What to use: Stone, pail, balance, string, chalk.

What to do: Weigh the stone in the air. Fill a pail about half full of water, and make a mark at the surface of the water. Lower the stone into the water, and weigh it again. Mark the pail at the surface of the water.

Take out the stone, and weigh the pail of water. Fill it to the second mark, and weigh the pail again.

What was observed: How much did the stone weigh in air? In water? How much weight did it lose? Did the water rise in the pail? How does the increase in the weight of the pail, when water is added, compare with the loss of weight of the stone?

What was learned: Select the correct conclusion.

(*a*) The stone loses weight equal to the weight of the water it displaces.

(*b*) The water added to the pail weighed just as much as does the stone in air.

(*c*) The stone sinks in the water because the pail is not full.

——Things to think about——

Write the numbers from 1 to 10 on a piece of paper or in your notebook. Complete the following sentences to make true statements. Opposite each number write the word needed to complete the sentence.

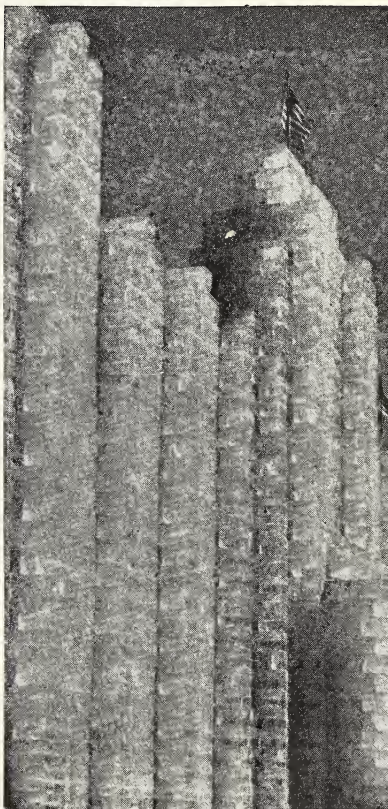
The ocean is —1— per cent salt and other solids. The weight of the iron in a boat is —2— than the weight of an equal amount of water. Power is taken from running water by use of —3—. Before the invention of steam engines and other more modern means,—4—was the most important source of power. An overloaded boat will sink because the weight is greater than the weight of the —5— of water displaced. Transportation by water is the —6— and —7— of all methods. A —8— amount of the water power available is used by man. A —9— waterfall possesses more power than a —10— one.

——Science activity for fun——

Put an egg into water. Does it float or sink? Add salt to the water, a little at a time, until the egg will not sink. Repeat the experiment

The solid form of water is ice. The walls of this ice palace were so strong that it was necessary to break them with dynamite to make them fall. Yet in the spring the rays of the sun cause ice to disappear.

Eugene Rosing photo



with a stale egg. Can you tell when an egg is stale by this method?

A Review of the Unit

Living things depend upon water to maintain conditions which make life possible. Water may exist as a solid, a liquid, or a gas. Ice contains the least energy and absorbs heat readily from everything around it. As a liquid, water is capable of dissolving nearly all substances. Because of this ability, water is easily the most important agent on the earth for transferring and changing materials. In the vapor state, water is transported great distances and to higher levels where it cools, condenses, and falls to the earth's surface to add to the water running back to the sea. This is the water cycle, which serves us in many ways. As the water returns to lower levels, it is a source of power and a means of transportation for shipment of freight and passengers.

An exercise in thinking

Below are two groups of sentences. The first group contains principles, which are large general ideas. Each sentence in the second group contains an idea related in some way to one of the principles in the first group. Write the numbers from 1 to 29 on a piece of paper or in your notebook. Find the principle which best explains the idea in the second list. Then after the number on your paper write the letter before the related principle.

Example: Snow is a form of water.

The correct letter for the example sentence is ***C*** *because snow is formed when water in the air is cooled below freezing.*

List of principles

A. Life cannot exist without water.

B. Water is not a simple substance but a compound composed of two elements, hydrogen and oxygen.

C. Gain or loss of heat must occur before water can change its state.

D. Water is capable of dissolving nearly all substances.

E. Plants and animals depend upon water to carry certain dissolved materials.

F. The change from water to vapor and back to water is called the water cycle.

G. The amount of work water can do depends upon the distance it can fall.

H. An object will float if it is lighter than the displaced water.

List of related ideas

1. The ocean contains many chemicals.
2. The formula for water used by the chemist is H_2O.
3. We can ice skate outdoors only in winter.
4. When water in a teakettle boils, steam is formed.
5. Blood is principally water.
6. Most living things need large amounts of water.
7. An iron boat will float, although the iron itself would sink.
8. Water is evaporated and the vapor condensed in distillation.
9. Plants obtain necessary water through their roots.
10. Water turns wheels which run machines.
11. Rain water differs from ocean water because it contains no salt.
12. Water appears on the outside of a glass of ice water.
13. Clothes dry in the sun.
14. When hydrogen-filled balloons explode, water is formed.
15. Most regions depend upon rainfall for water.
16. Ice in a refrigerator gradually disappears.
17. Dissolved lime in water does not spoil water for drinking purposes.
18. Water can be separated into hydrogen and oxygen.
19. Limestone caves are formed by water containing carbon dioxide seeping through rocks.

20. Water often drips from cold pipes in moist weather.
21. The terraces of Yellowstone Park are deposited by water.
22. It is thought that the first life appeared in water.
23. Hail sometimes forms in clouds in summer.
24. Water containing lime does not hold soapsuds well.
25. Water evaporated from a kettle may condense on the window.
26. We must have pure water to drink.
27. When we are wet, our skin feels cold.
28. Snow melts in the spring.
29. Scale often forms on teakettles.

An exercise to test yourself

Write the numbers from 1 to 10 on a piece of paper or in your notebook. Opposite each number write the letter before the word or group of words which best completes the sentence.

1. A means of recreation which does not depend upon water is (*a*) fishing (*b*) skating (*c*) boating (*d*) swimming (*e*) flying kites.
2. Impure water may be made safe for drinking by (*a*) testing it (*b*) adding carbon dioxide (*c*) boiling it (*d*) straining it.
3. The changing of water to vapor is called (*a*) melting (*b*) evaporation (*c*) condensation (*d*) freezing.
4. A pint of water when freezing will make (*a*) less than a pint of ice (*b*) more than a pint of ice (*c*) a pint of ice exactly.
5. Separating liquids from solids by heating and then cooling the vapor is called (*a*) boiling (*b*) solution (*c*) distillation (*d*) condensation.
6. The least important use of rivers is (*a*) as a source of water power (*b*) as a source of city water (*c*) for disposal of sewage (*d*) for navigation (*e*) providing state boundaries.

7. Gas in the sewer is kept out of the house by (*a*) faucets (*b*) cut-off valves (*c*) traps (*d*) leather washers.

8. Water is (*a*) a compound (*b*) an element (*c*) a solution.

9. Lime in water is usually (*a*) in flakes (*b*) suspended (*c*) dissolved (*d*) heated.

10. Water changes from one form to another because of changes in (*a*) weight (*b*) volume (*c*) position (*d*) heat.

Some things to explain

1. How many different situations can you describe in which ice forms? *For example: on airplane wings.*

2. Find all the liquids in your home. How many are made of some substance dissolved in water? In alcohol?

3. How are stalactites and stalagmites formed in a cave?

4. List as many ways as you can in which water is used for cleansing.

5. How can you purify salt water?

6. Is an iceberg made of fresh water or salt water?

Some good books to read

Broadhurst, J., *Home and Community Hygiene*
Compton's Pictured Encyclopedia
Fisher, Irving and Fisk, E. L., *How to Live*
Innes, W. T., *The Modern Aquarium*
Meister, M., *Water and Air*
Thompson, J. M., *Water Wonders Every Child Should Know*
Whitman, W. G., *Household Physics*

SOME SCIENCE WORDS

This list includes all the words for which *pronunciations* and *formal* definitions are given in the text. The page numbers refer to those pages on which the words are pronounced or defined. Where a definition is omitted in this list, it means that the word is pronounced and *informally explained* on the page given, and therefore no *formal* definition is added here. See page v in the front of the book for an explanation of the method of pronouncing and defining the words in this book.

adenoids, p. 326
alkaline, p. 353
altimeter, p. 303
amoeba, p. 31
amphibian, p. 45
Antares, p. 106
arthropods, p. 37
astronomer, p. 282
atmosphere, p. 279
Auriga, p. 118

bacteria, p. 316
barometer, p. 298
basalts, p. 188
Betelgeuse, p. 118
bromine, p. 374
butte, p. 215

cambium, p. 69
Capella, p. 119
chameleon, p. 46
chemistry, p. 312
chitin, p. 37
chlorophyll, p. 63
cilia, hairlike growths on cells used to produce movement, p. 32
compressed, p. 288
concentrate, p. 209
conglomerates, p. 189
conifers, plants that bear their seeds in cones, p. 76
constellations, p. 103
contact, p. 245
crustacean, p. 39
crystals, p. 143
cylinder, p. 286

decomposed, p. 343
dirigible, p. 285
distillation, p. 368
dunes, p. 157

elastic, p. 287
energy, ability to do work, p. 279, or to bring about changes, p. 254

erosion, p. 157
evaporation, p. 346

feldspar, p. 143
fermentation, p. 314
formula, p. 344
frond, leaf of the fern plant, p. 74

galaxy, p. 109
Galileo, an Italian scientist, p. 299
Gila monster, p. 46
glaciers, p. 142
gneiss, p. 144

Hercules, p. 112
hub, p. 236
humus, p. 165
hydrochloric acid, p. 351
hydrogen, p. 301
hypothesis, pp. 5 and 6

igneous, p. 188
impervious, p. 205
insulator, p. 261
irrigated, p. 354

kinetic, p. 254

Lavoisier, p. 309
levee, p. 160
lichen, p. 57
Linnaeus, a Swedish botanist who lived around 1750, p. 76

magnesium, p. 374
mesa, p. 215
metabolism, the process of using food and releasing energy, p. 54
metamorphic, p. 192
minerals, p. 354
molecules, p. 365
moraine, p. 159
mucus, p. 325

nichrome, p. 268
nitrogen, p. 307
nucleus, the central part of a cell, p. 53

Orion, p. 106
osmosis, the process by which water passes through the walls of root hairs, p. 68

paramecium, p. 32
parasites, fungi that use living matter for food, p. 72
Pasteur, p. 321
petioles, p. 70
photosynthesis, the process by which food is made, p. 62
pollen, p. 327
porous, p. 283
potential, p. 254
protoplasm, p. 53
ptarmigan, p. 88

quartz, p. 143

repel, p. 260
Rigel, p. 106

saprophytes, fungi that use dead matter as food, p. 72
sedimentary, p. 189
seismograph, p. 140

sequoias, p. 76
sinus, p. 325
Sirius, p. 107
soluble, p. 150
spectroscope, p. 125
sperm, p. 74
spores, p. 322
stalactites, p. 208
stalagmites, p, 208
strata, p. 161
stratosphere, p. 301
sulphuric acid, p. 343
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